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(54) **CLOT RETRIEVAL DEVICES**

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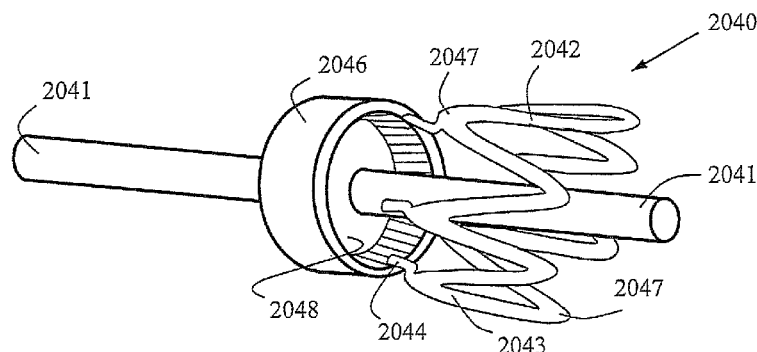
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**ABSTRACT**

A self-expandable mechanical clot retrieval device is designed variously to dislodge, engage and retract blood clot from extremely small and tortuous vasculature. The retrieval device comprises an elongate member and a plurality of ring elements. The ring elements may comprise a plurality of struts and crowns interconnected by a tether formed at a distal end of the elongate member or may be a separate component attached thereto. At least one tether may connect each ring element to the elongate member to restrain the ring element in a collapsed configuration during delivery of the retrieval device through an intravascular microcatheter. The tether connecting the ring element to the elongate member disengages when the retrieval device is positioned at the occluded site and the microcatheter is retracted to allow the self-expandable ring elements to reach an expanded configuration.

**30 Claims, 61 Drawing Sheets**



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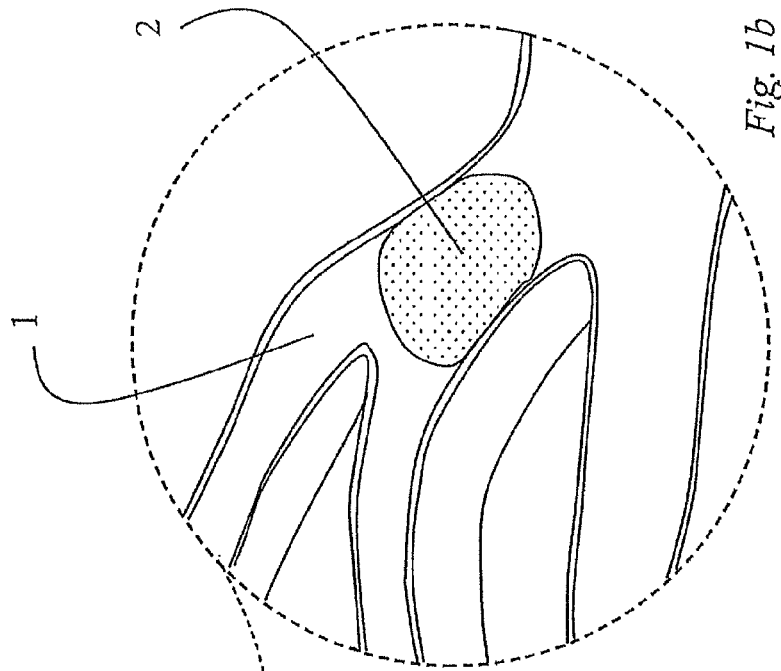


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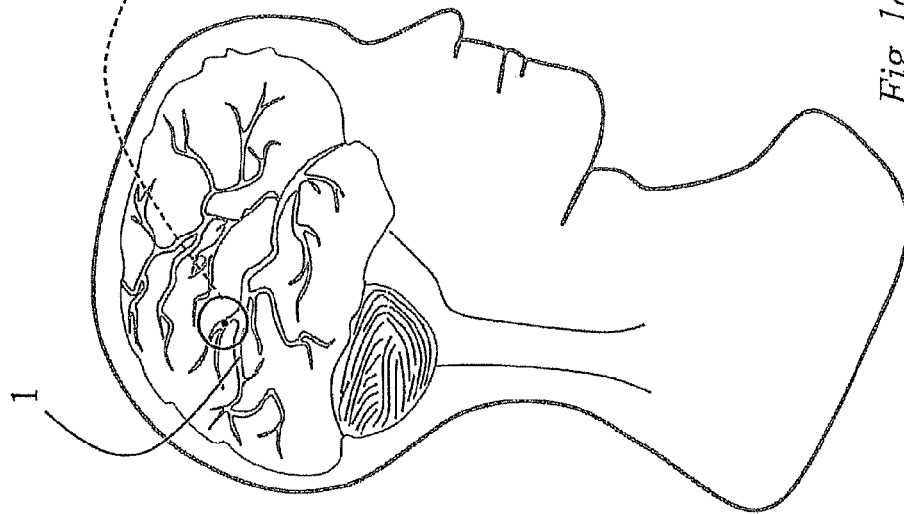


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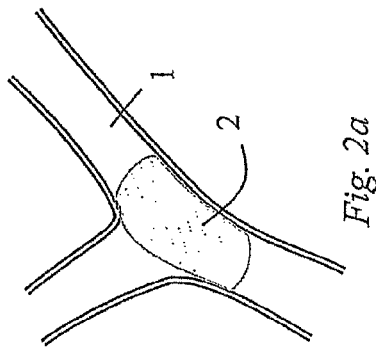


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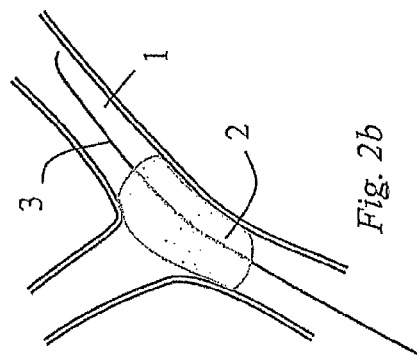


Fig. 2b

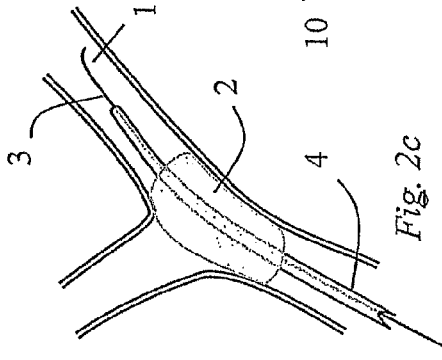


Fig. 2c

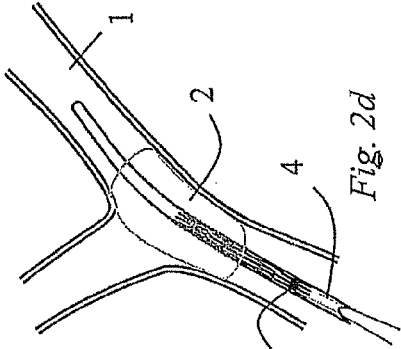


Fig. 2d

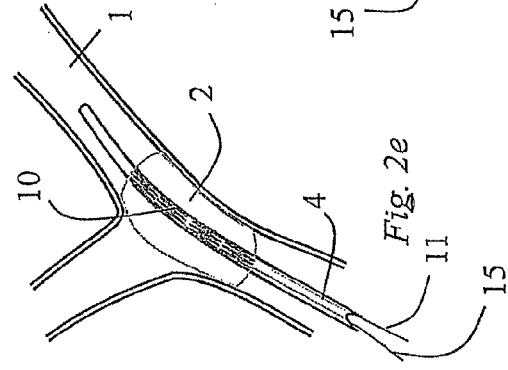


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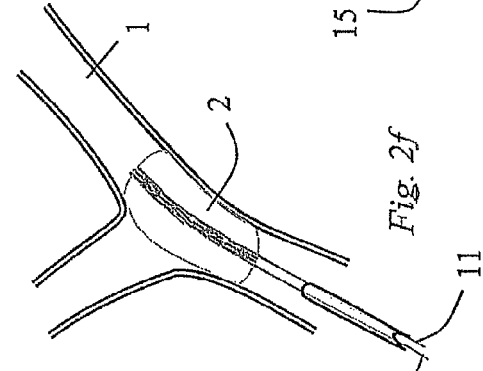


Fig. 2f

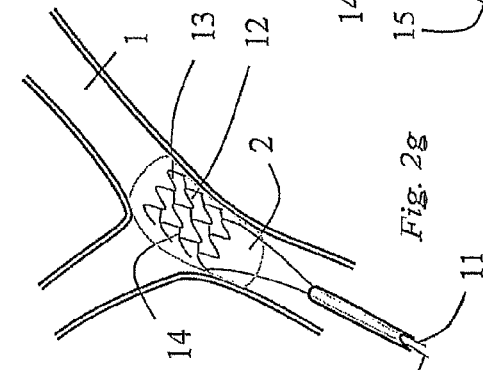


Fig. 2g

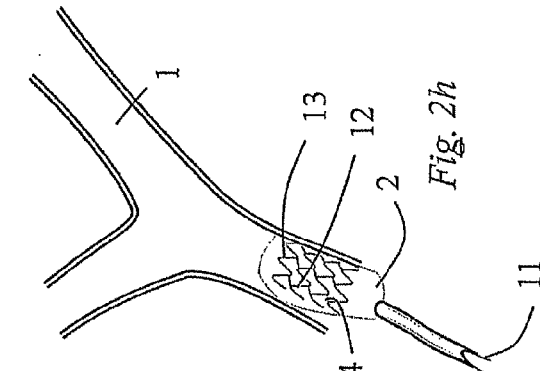
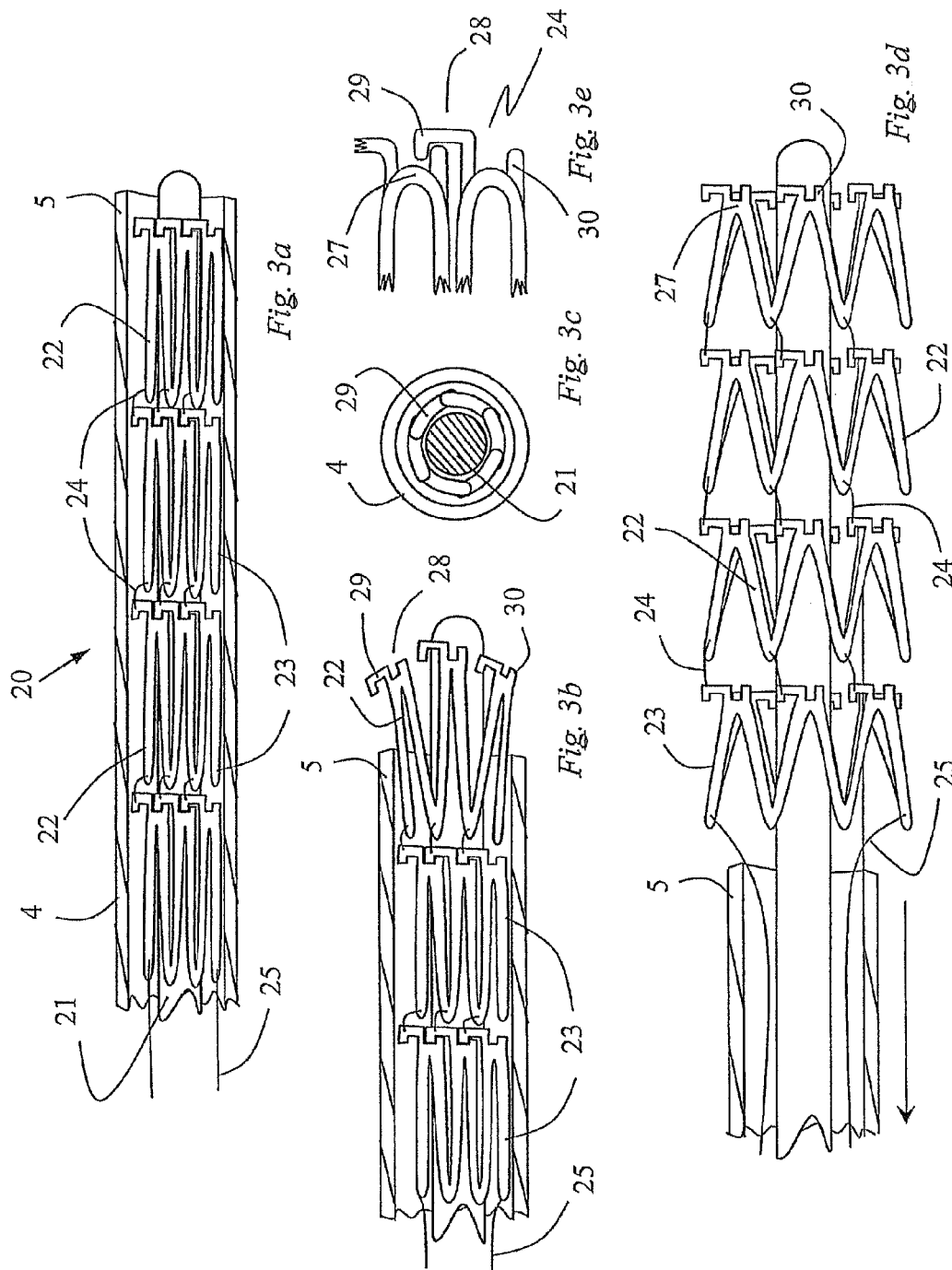
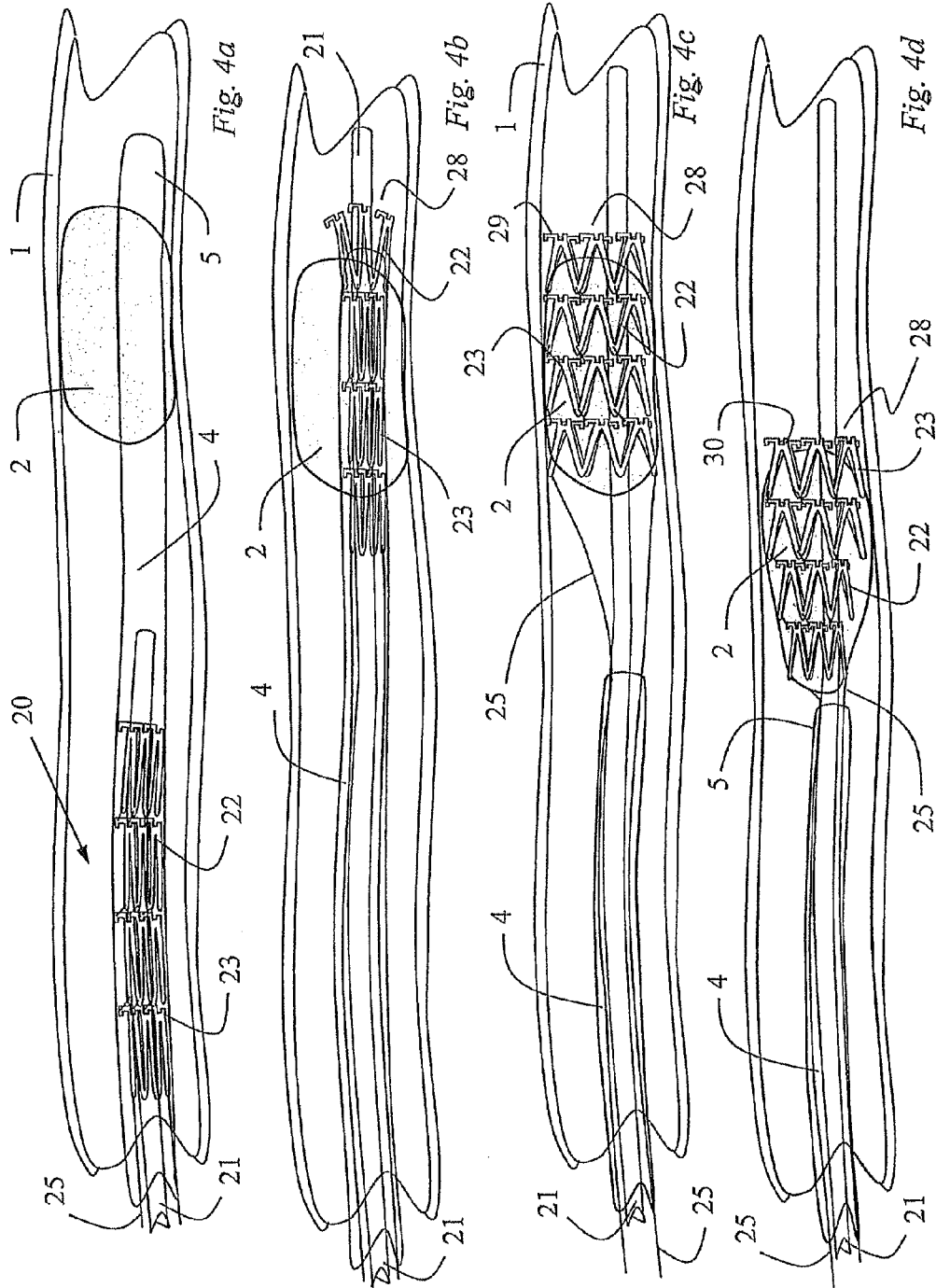
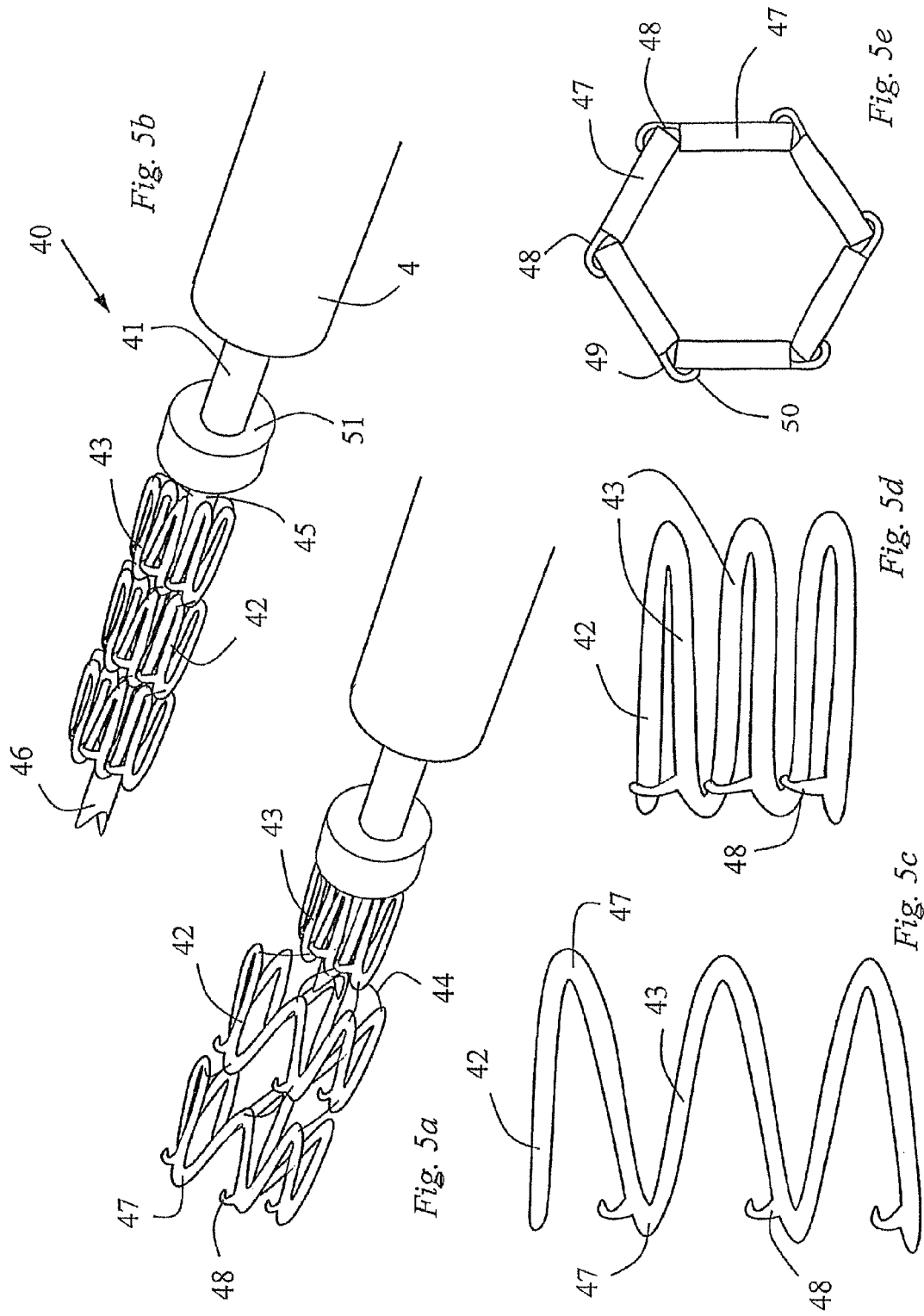


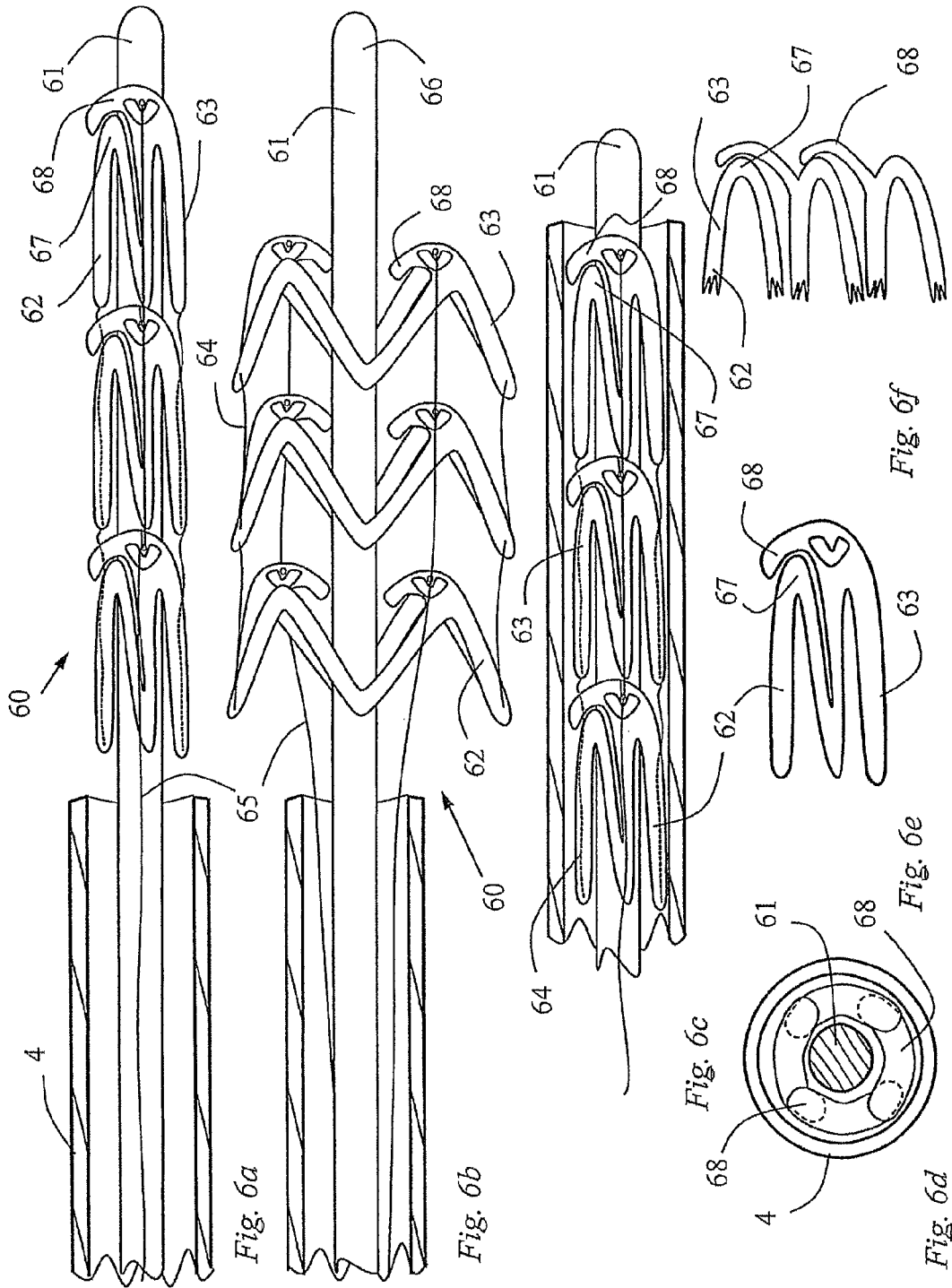
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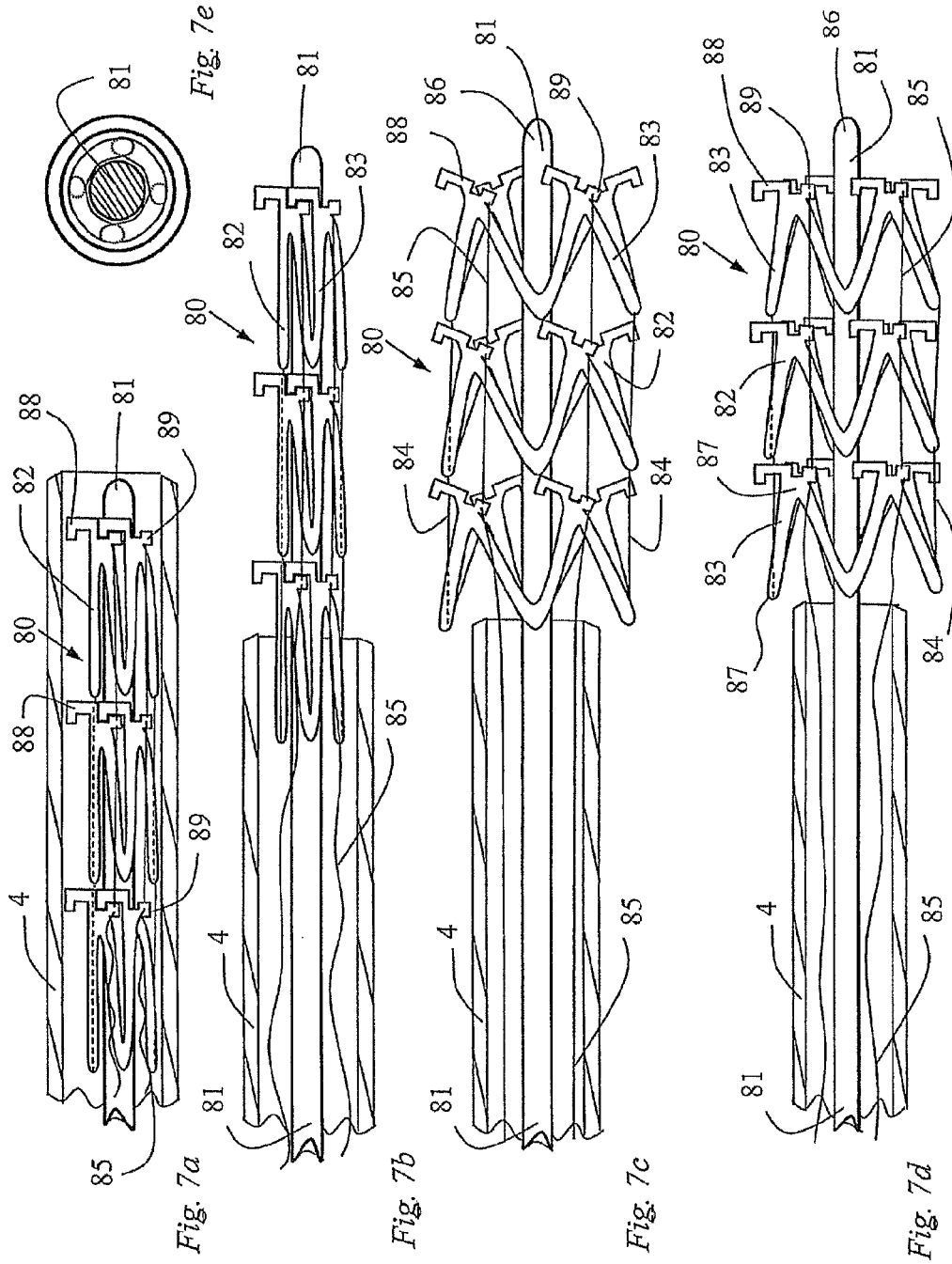


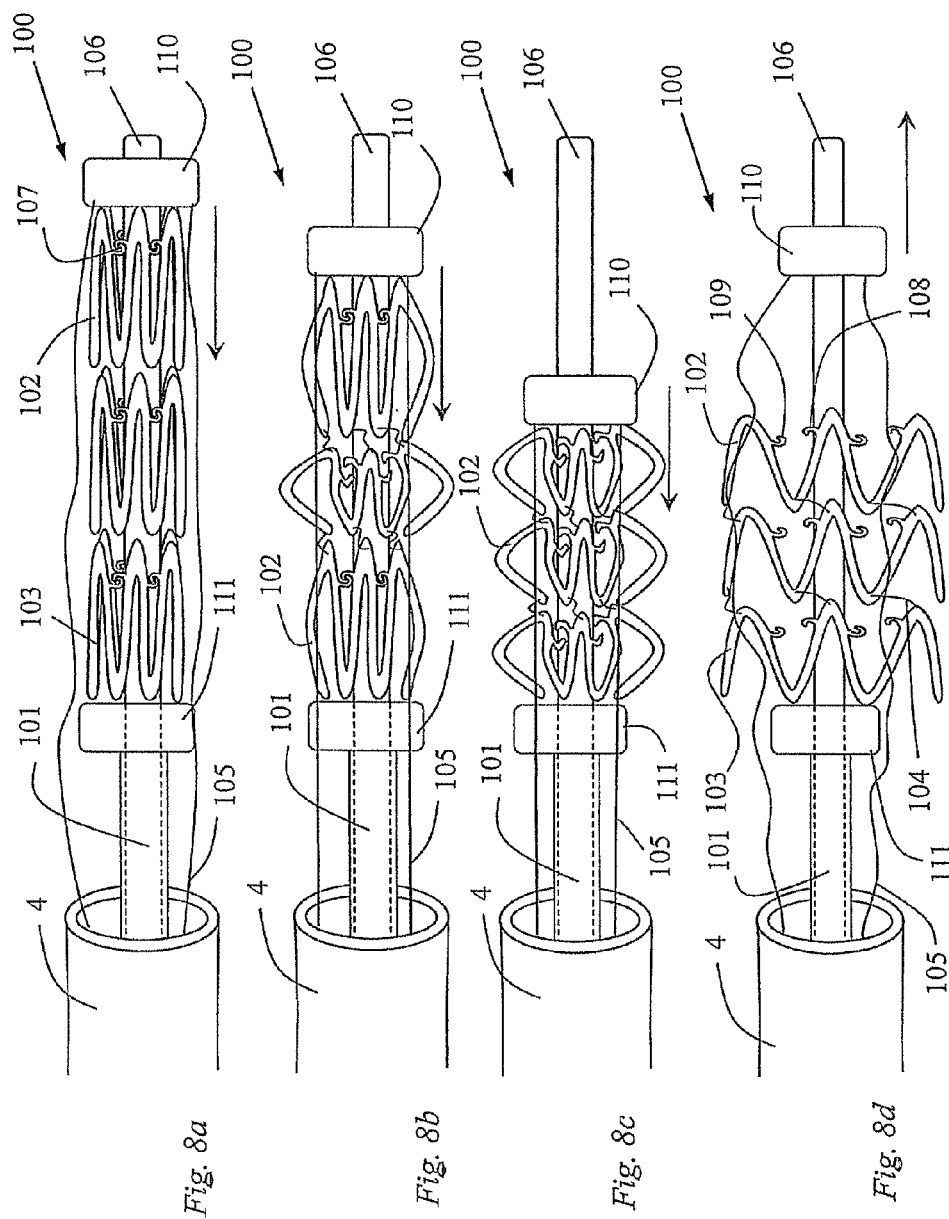


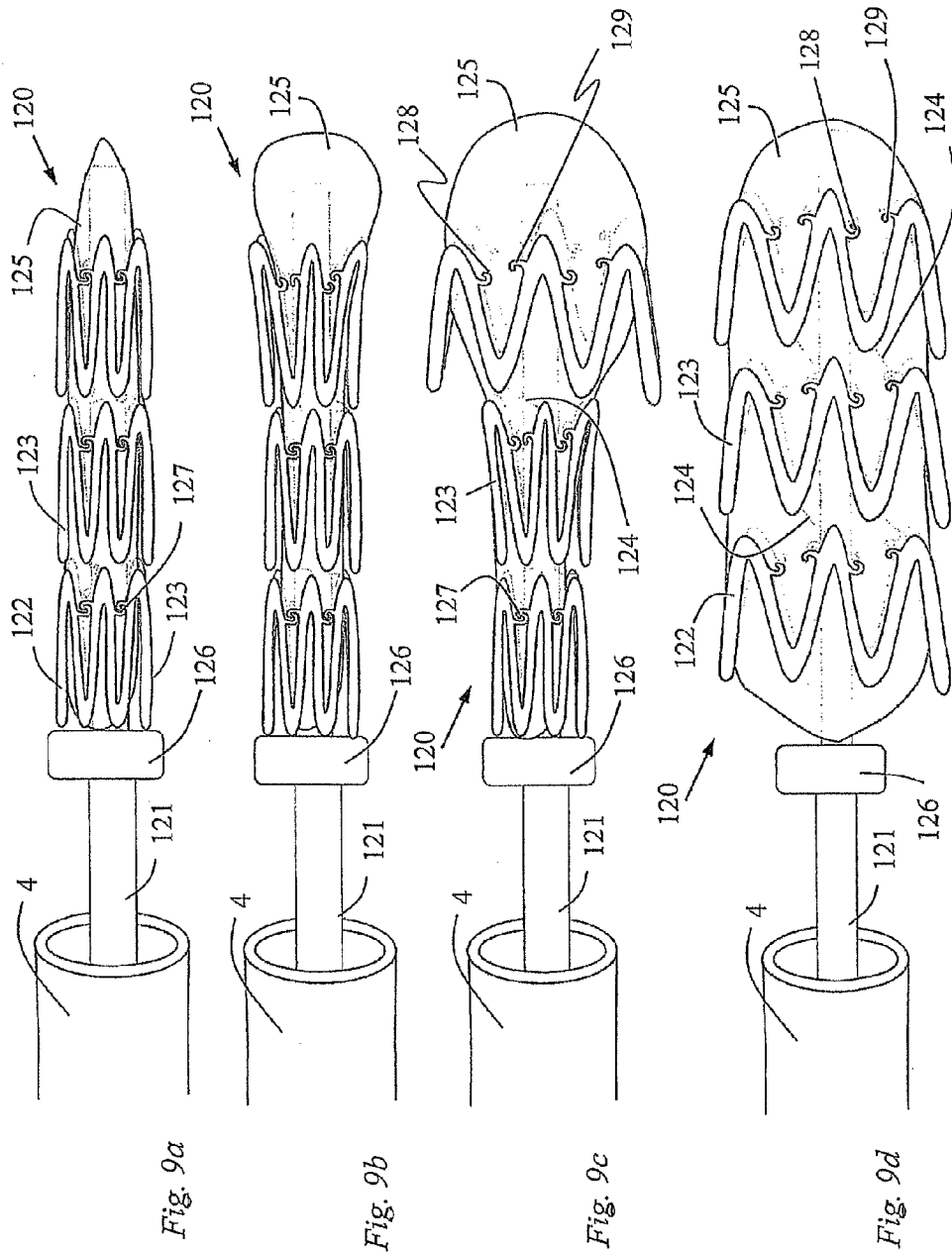












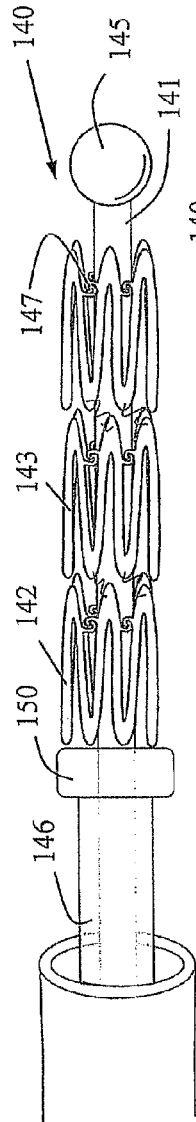


Fig. 10a

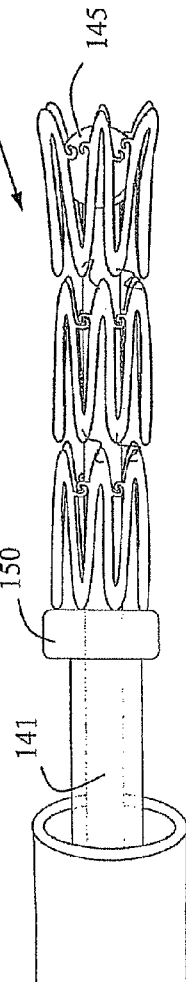


Fig. 10b

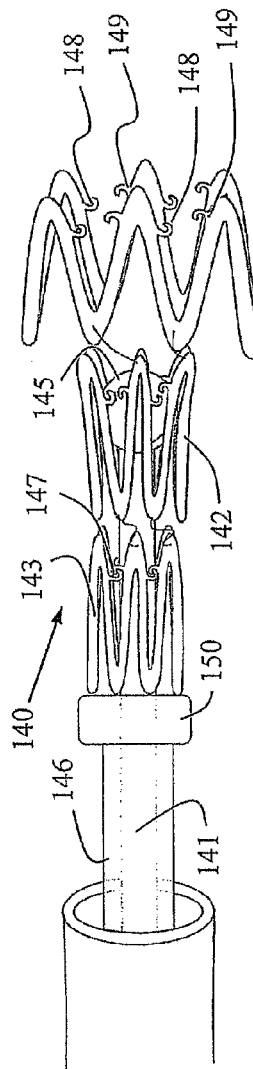


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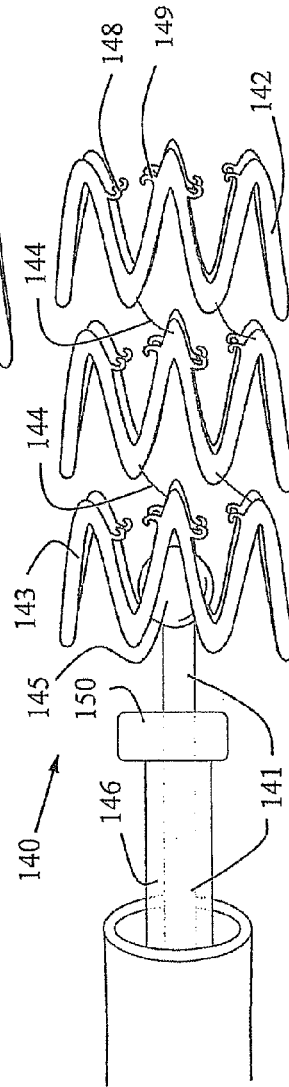


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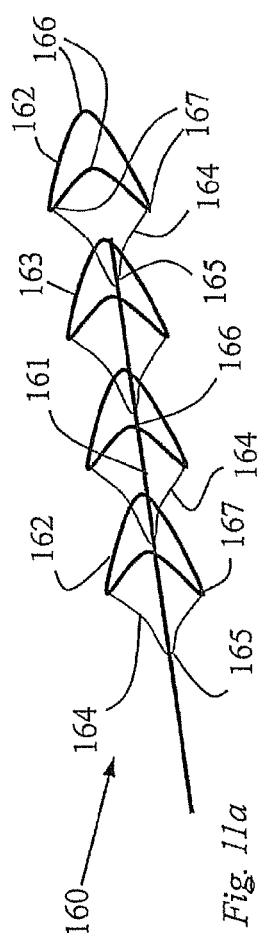


Fig. 11a

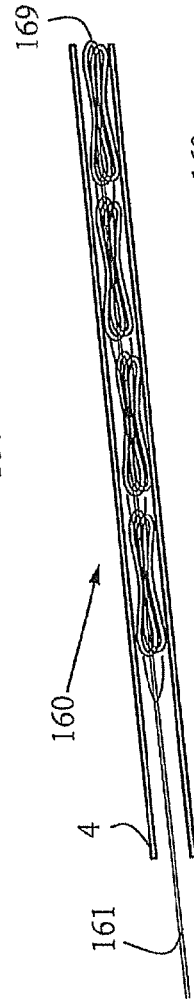


Fig. 11b

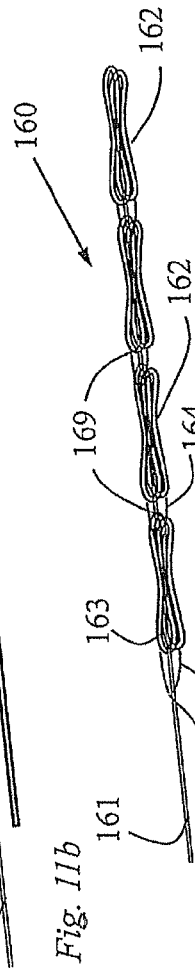


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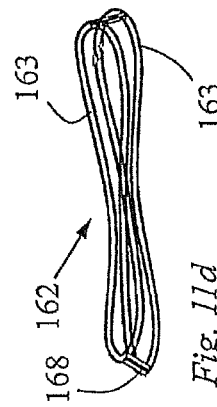


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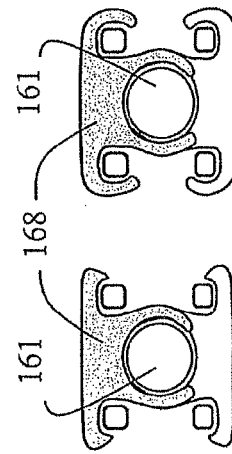


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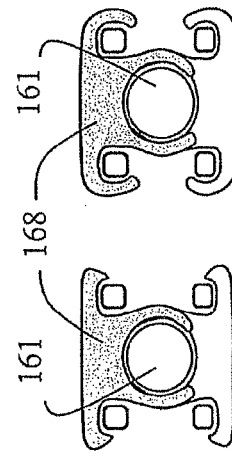


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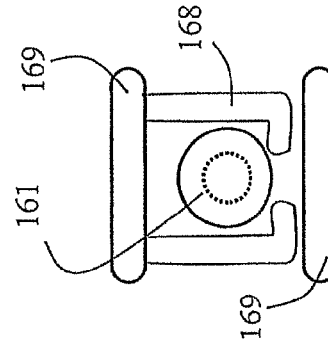


Fig. 11g

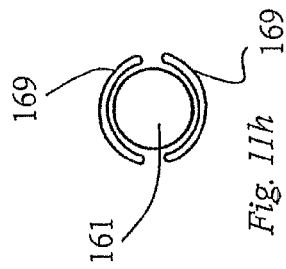


Fig. 11h



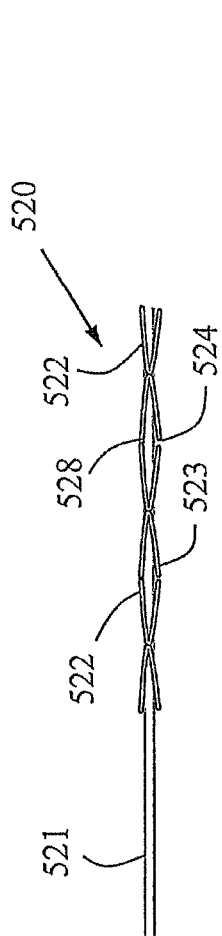


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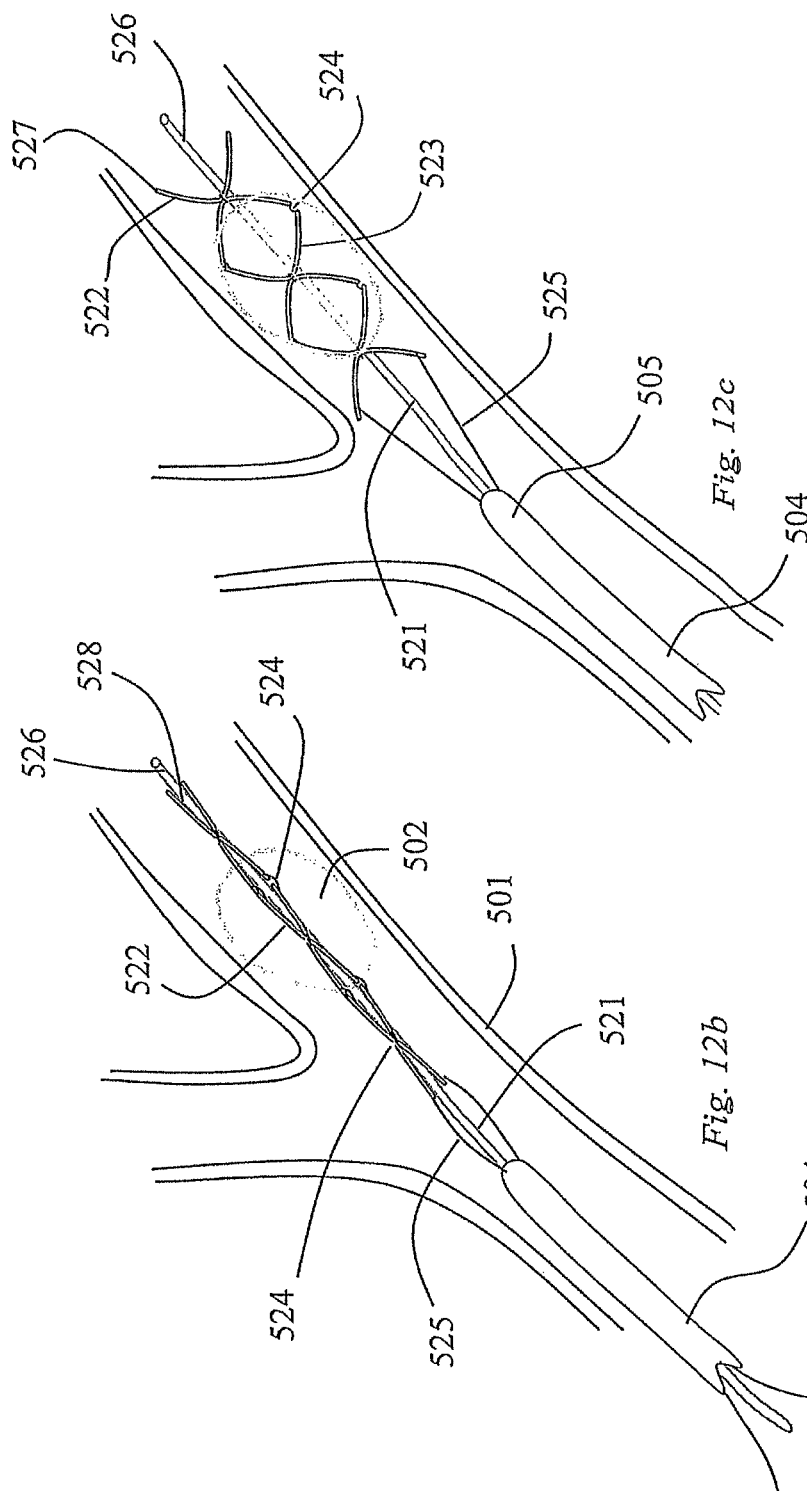


Fig. 12b

Fig. 12c

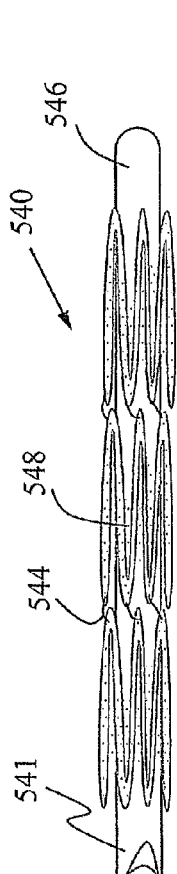


Fig. 13a

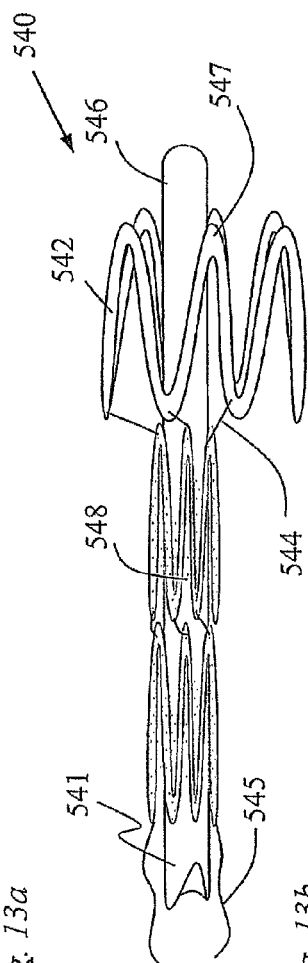


Fig. 13b

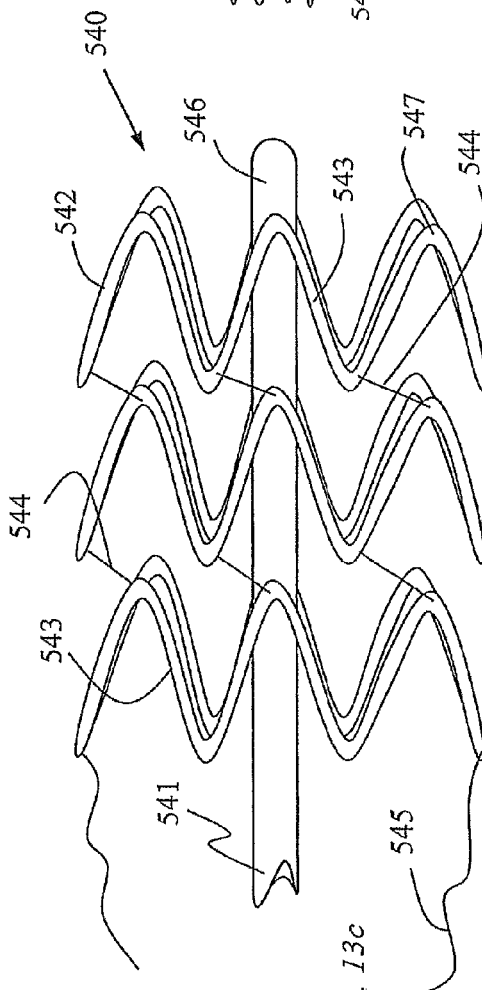


Fig. 13c

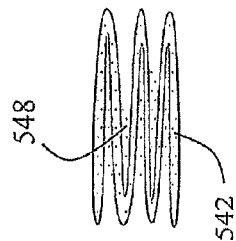


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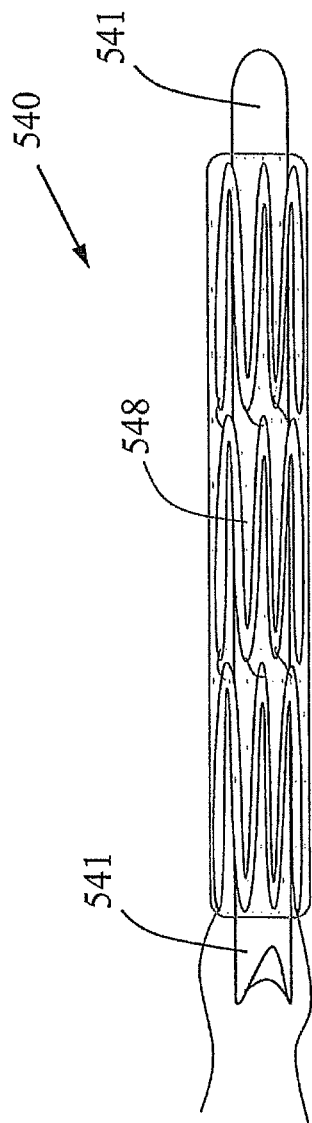


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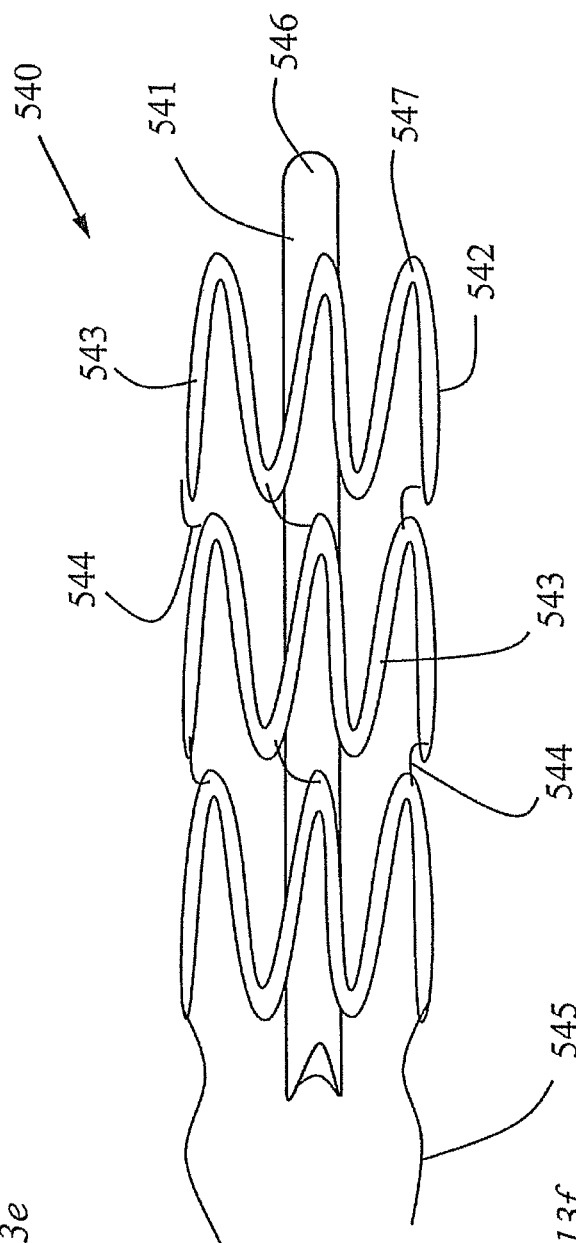


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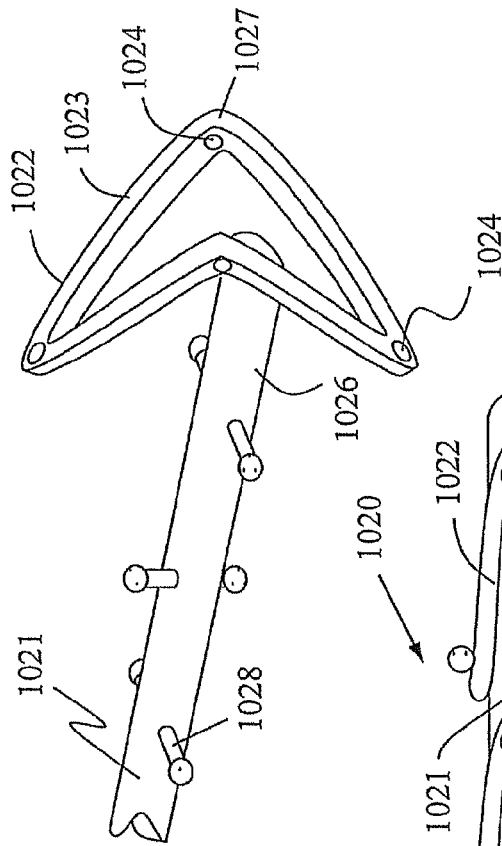


Fig. 14a

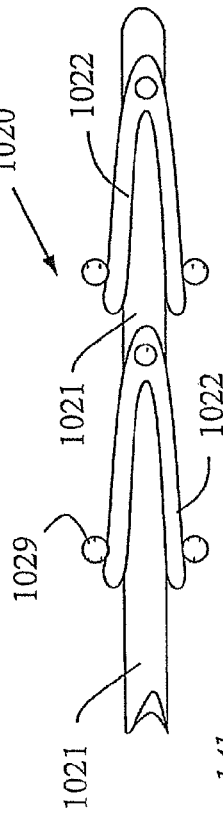


Fig. 14b

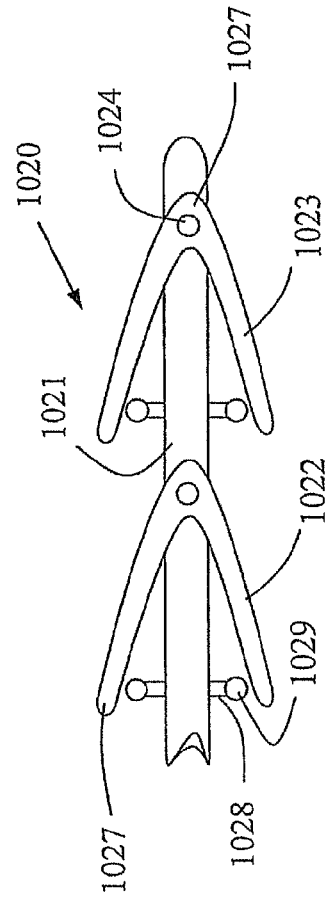
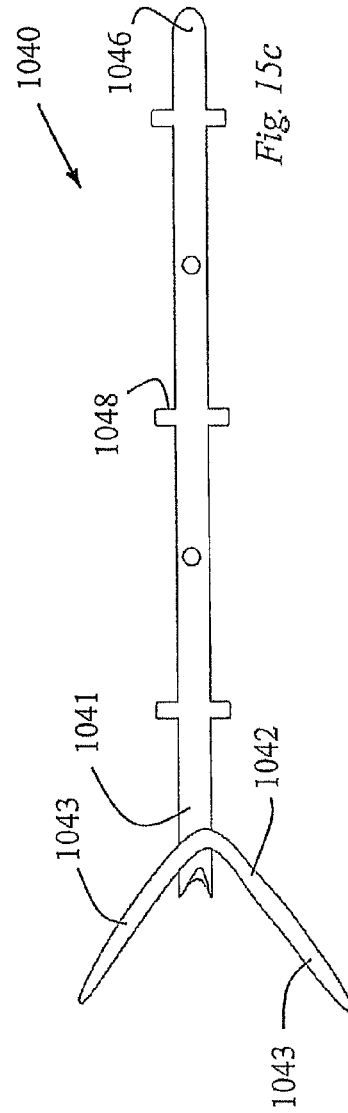
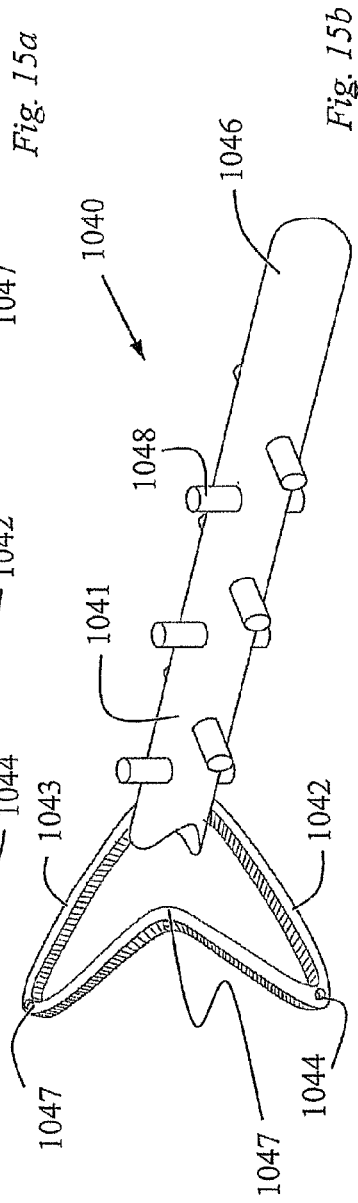
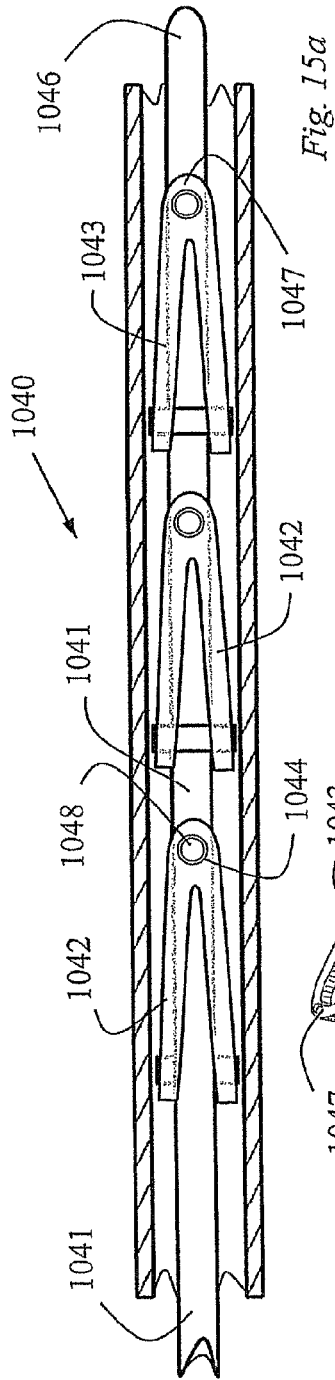
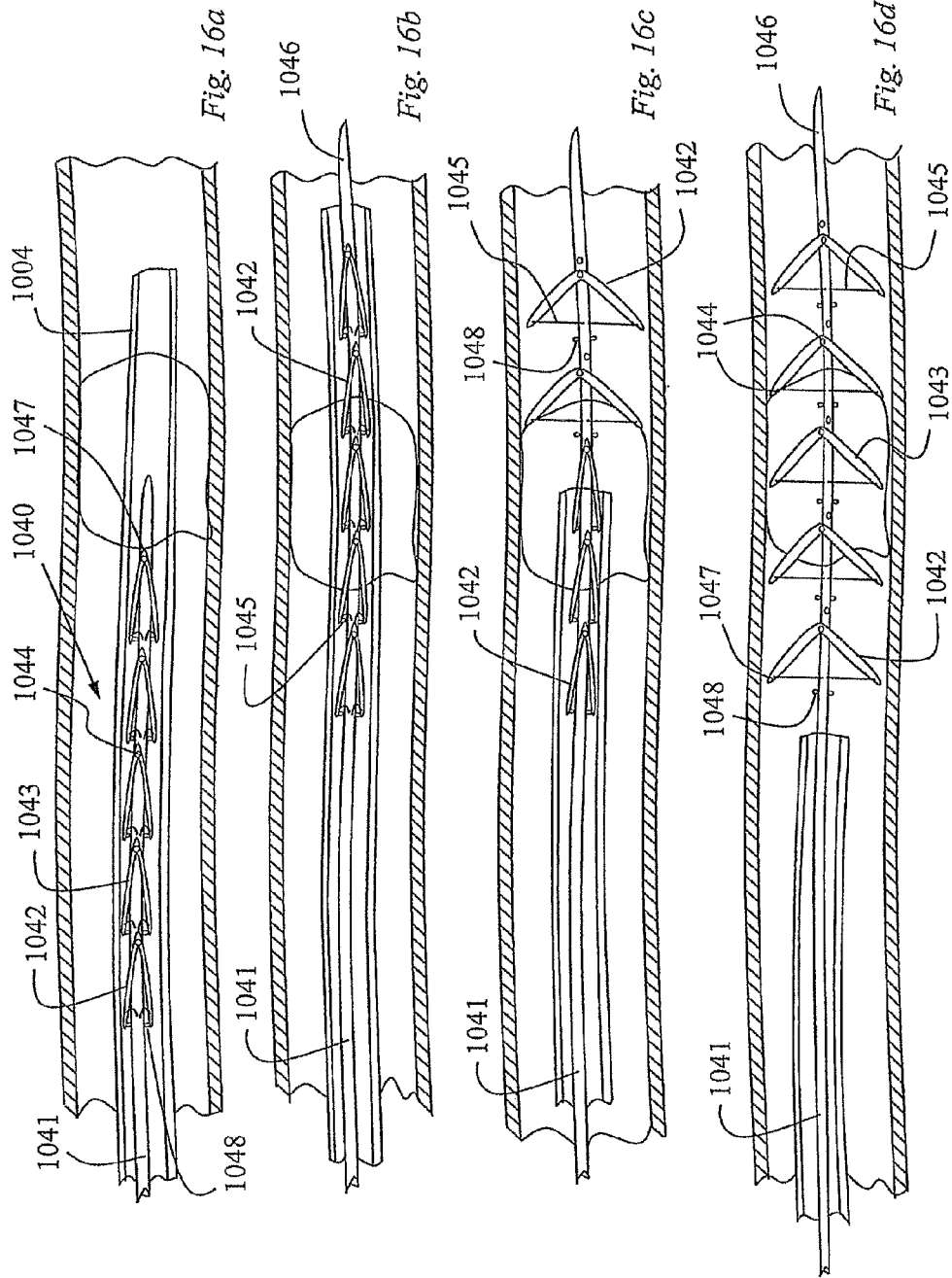
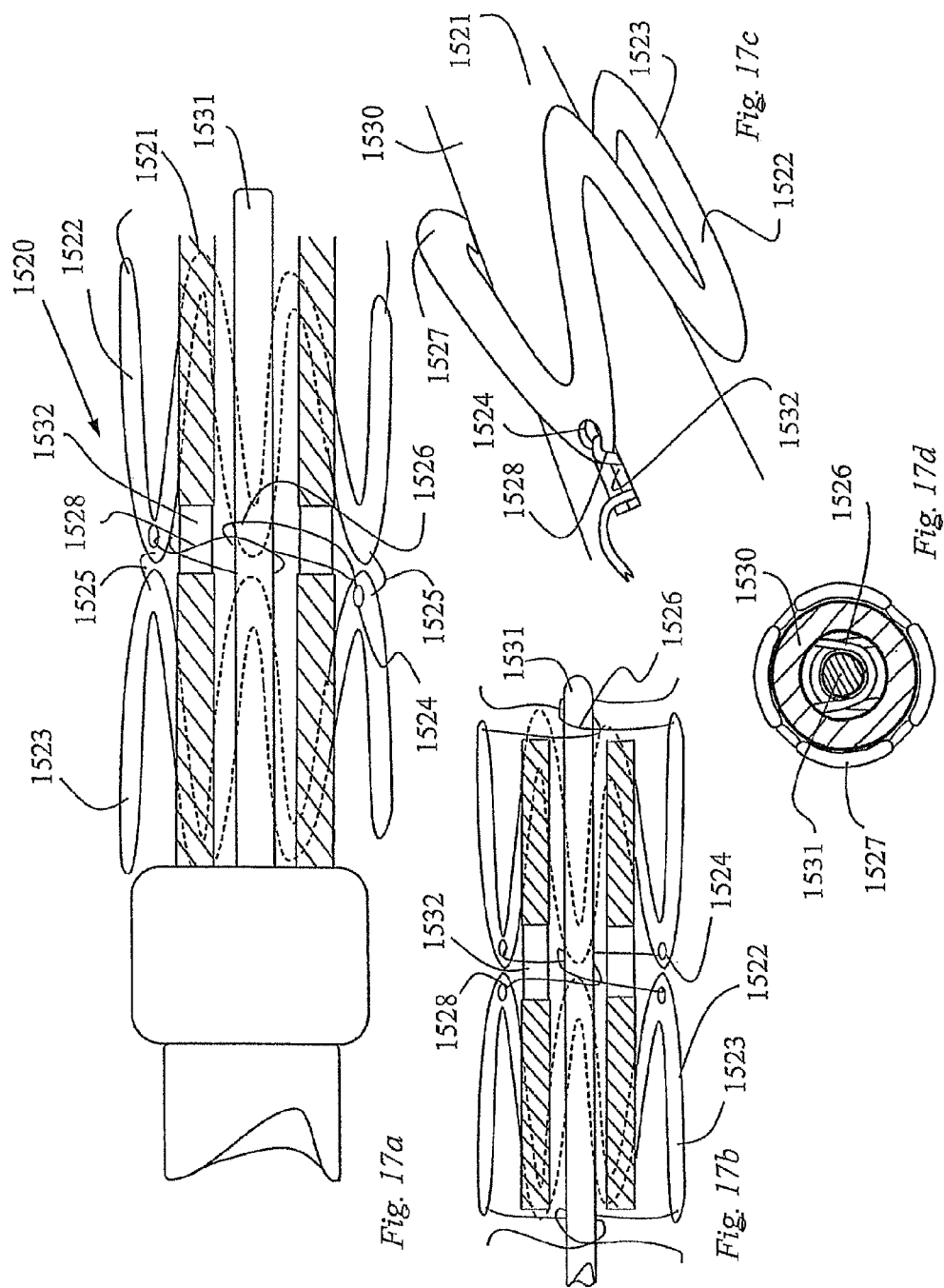
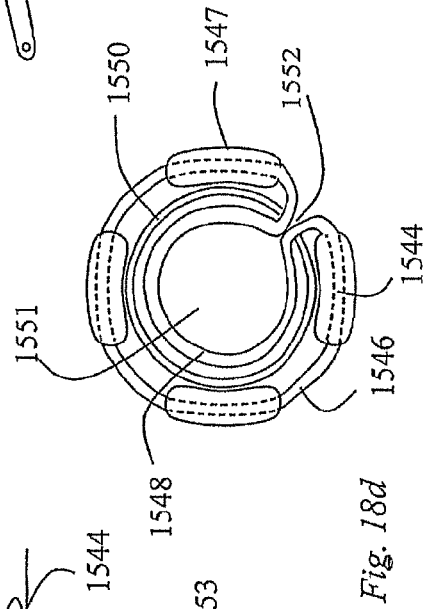
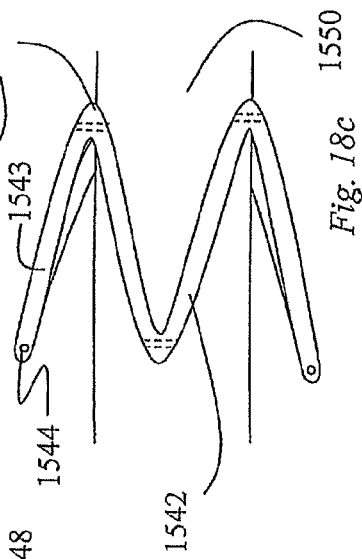
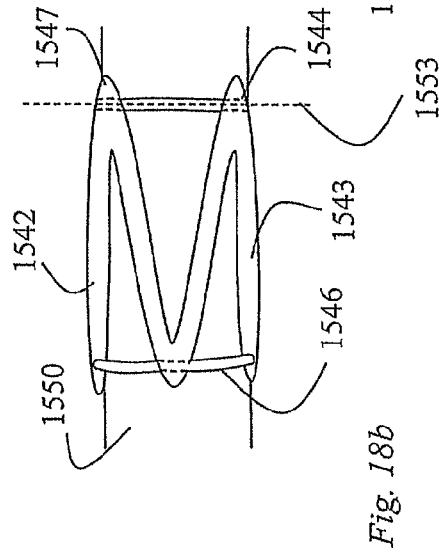
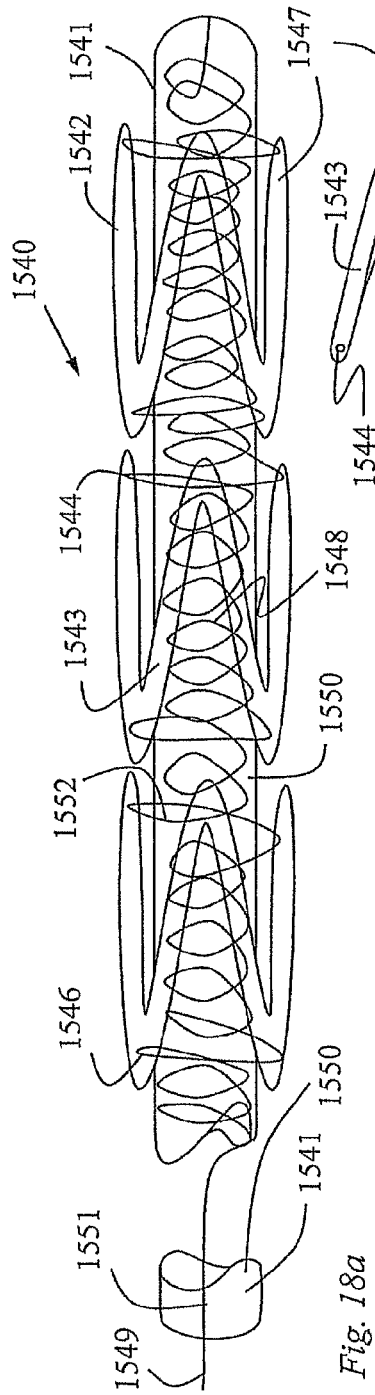


Fig. 14c











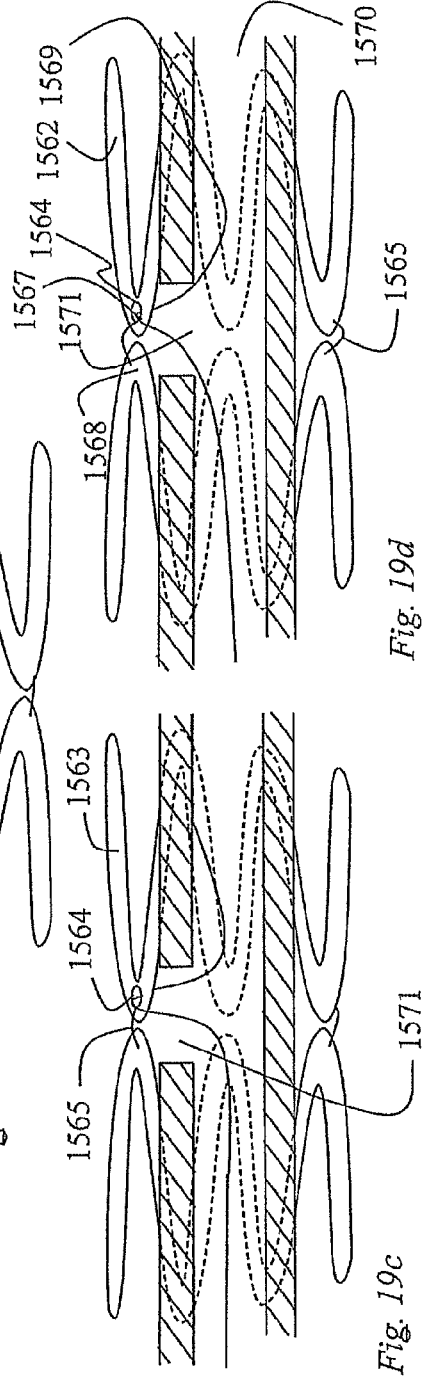
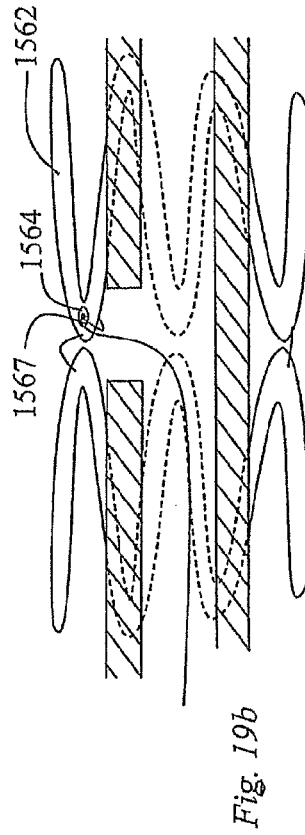
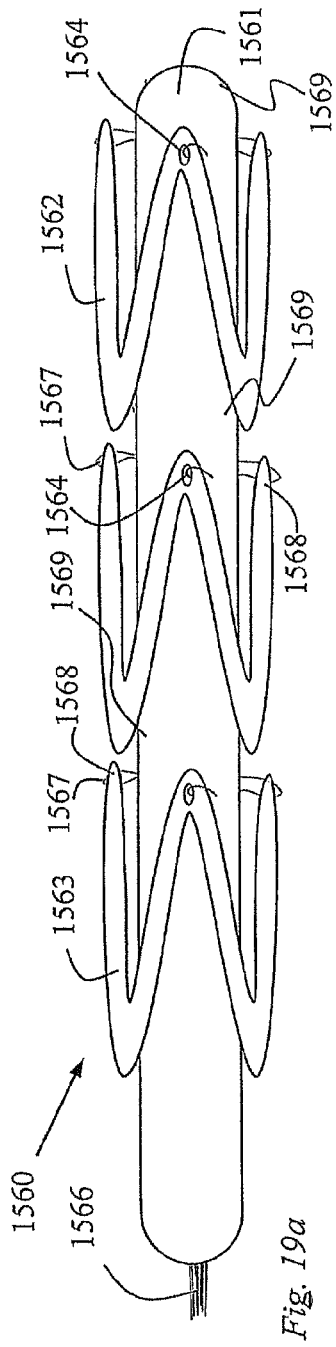


Fig. 19d

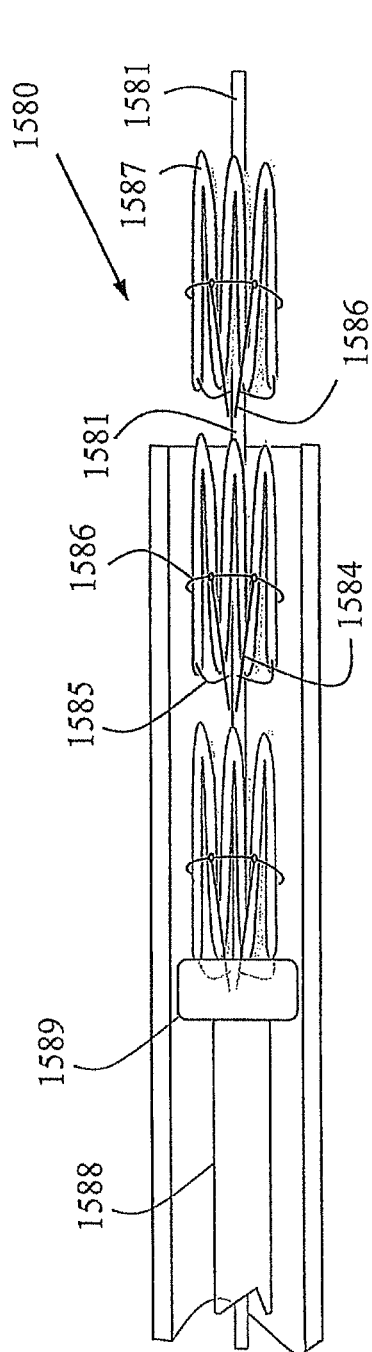


Fig. 20a

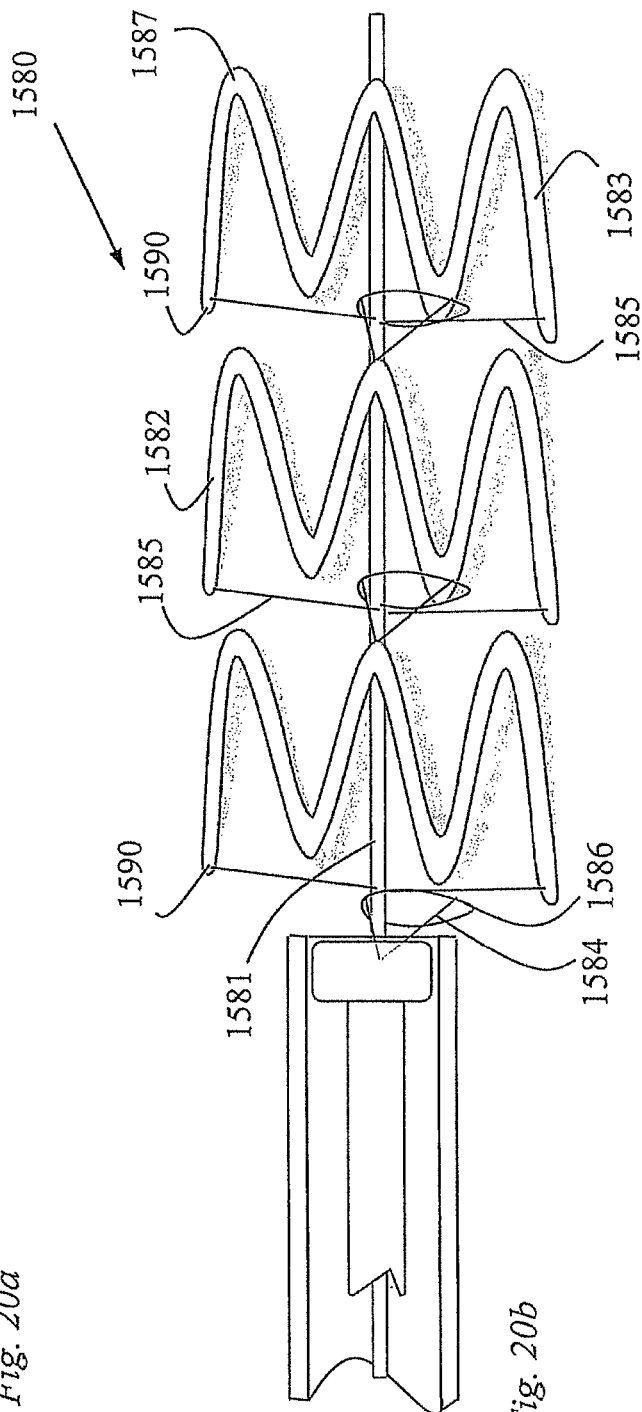
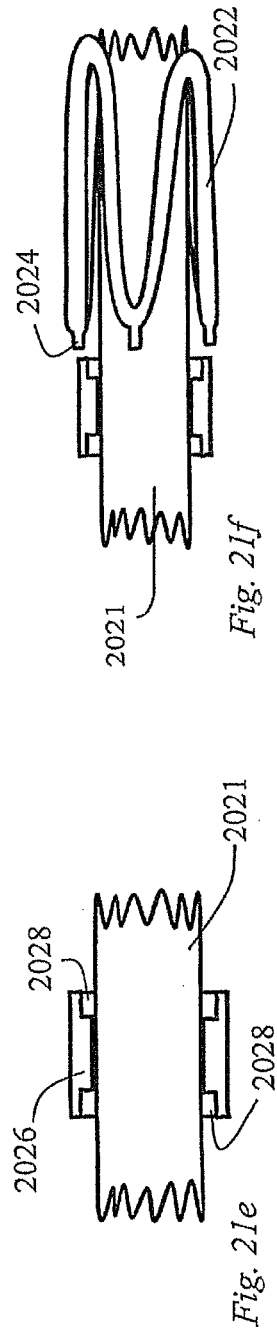
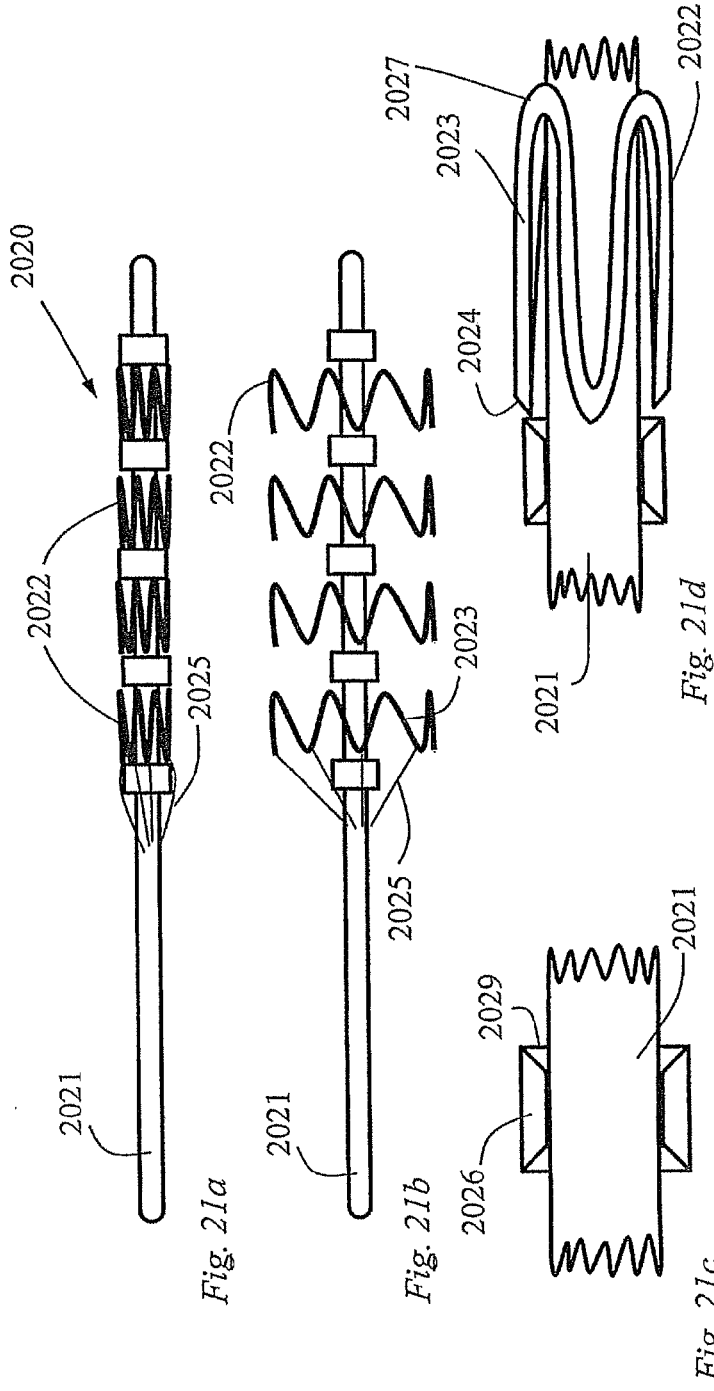
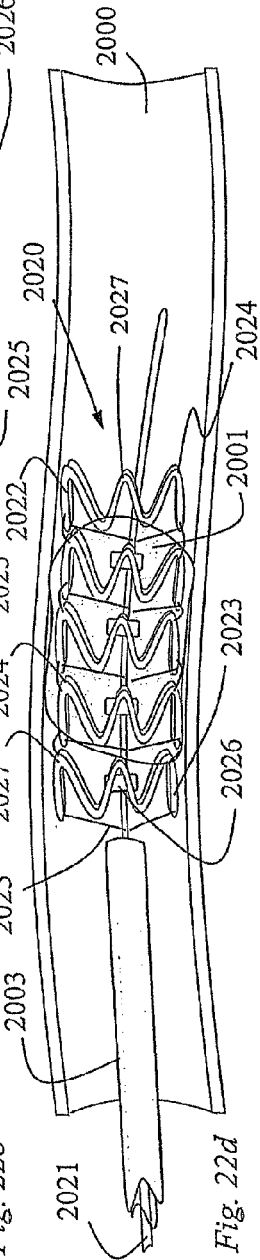
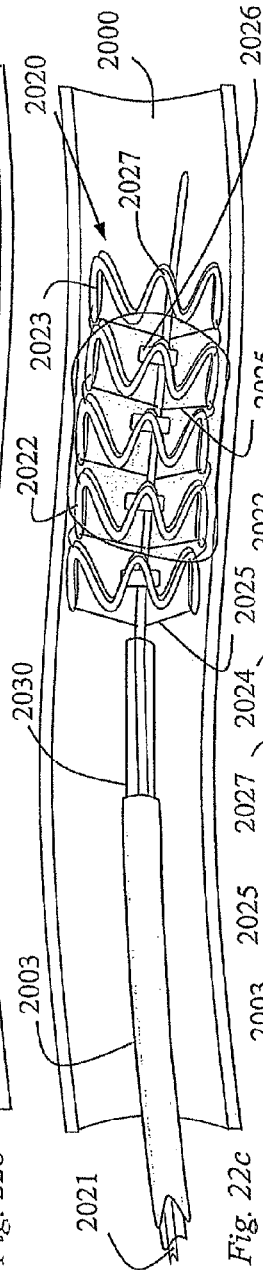
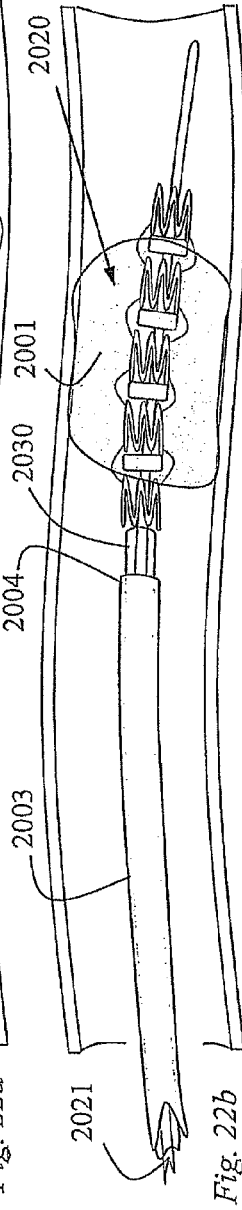
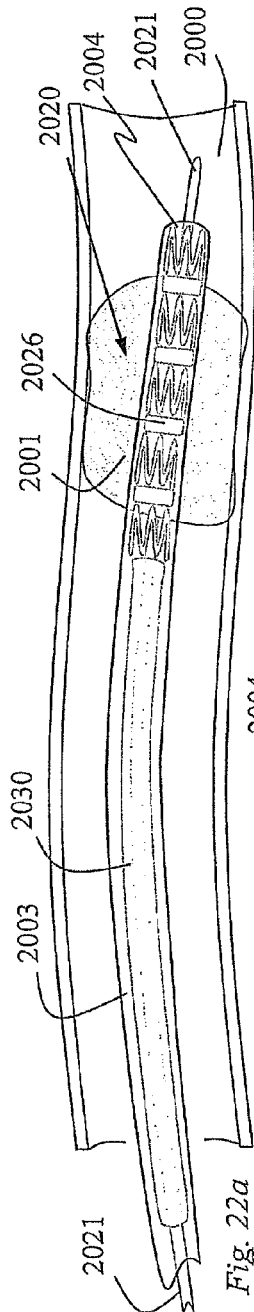
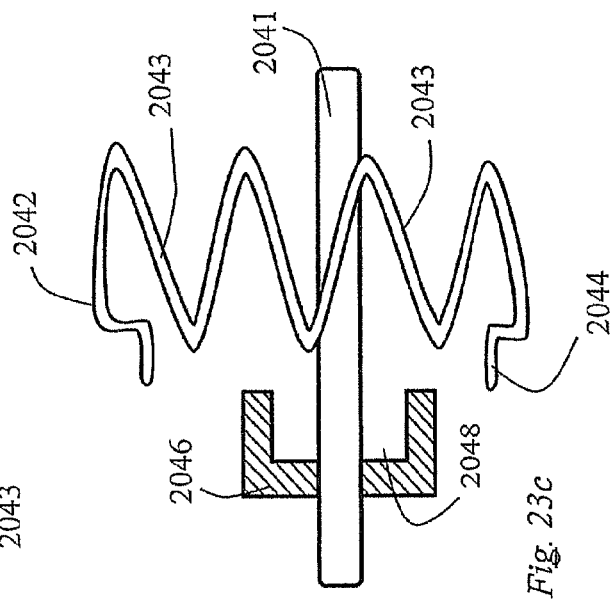
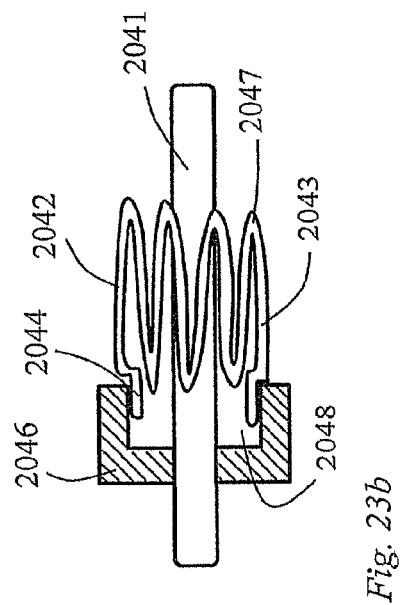
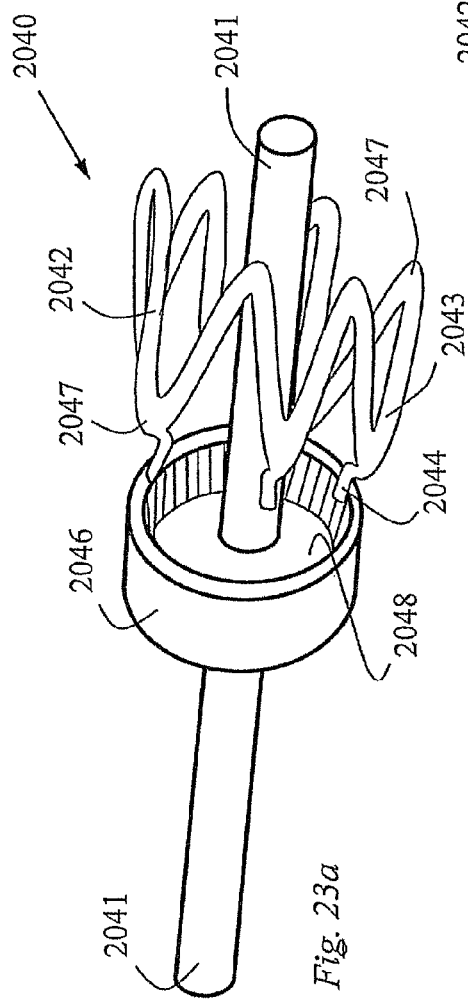


Fig. 20b







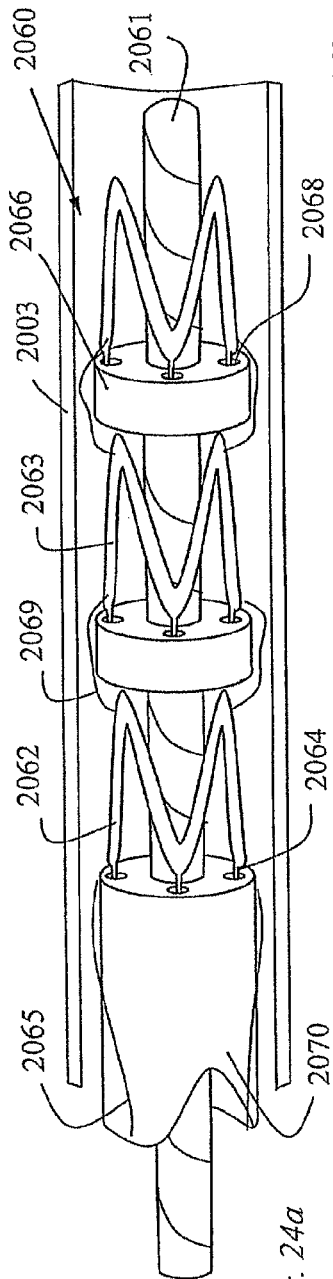


Fig. 24a

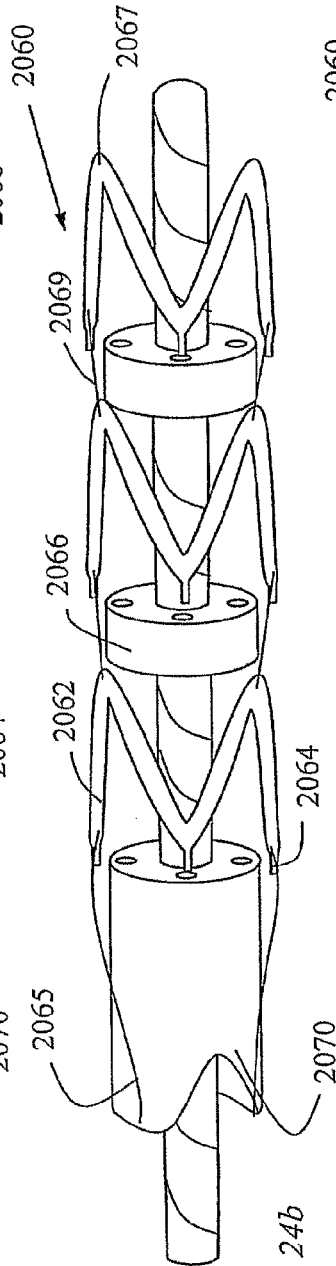


Fig. 24b

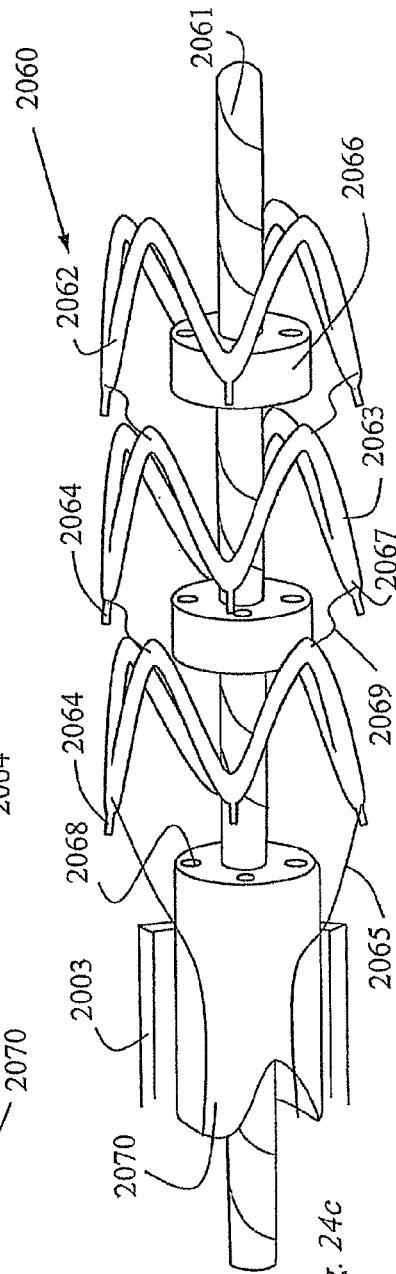


Fig. 24c

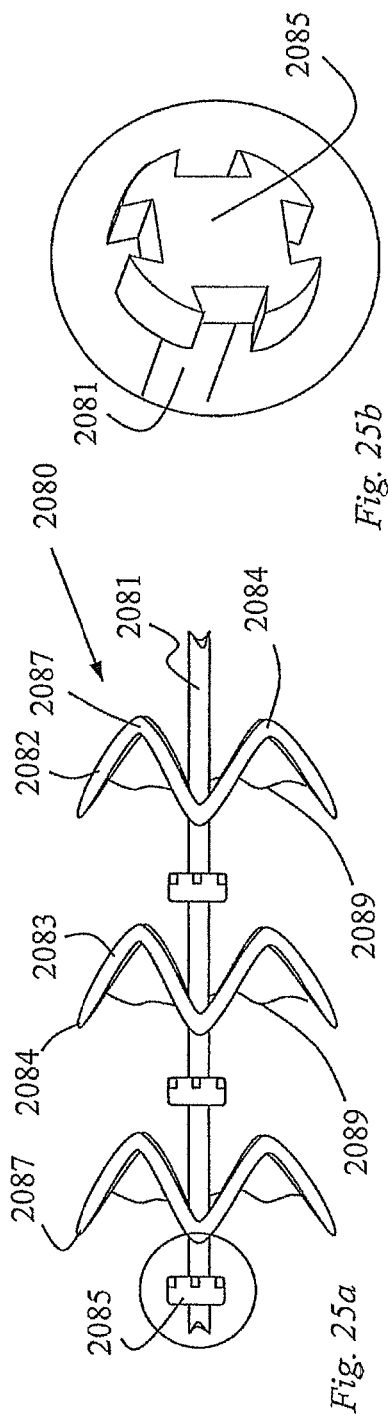


Fig. 25b

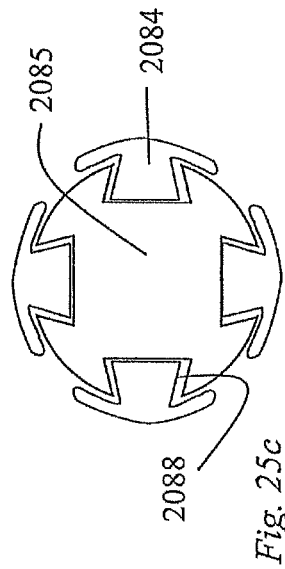


Fig. 25c

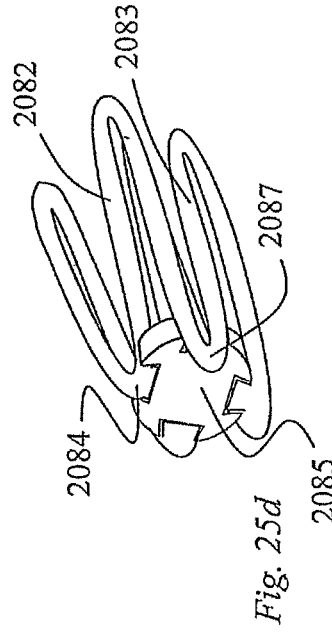


Fig. 25d

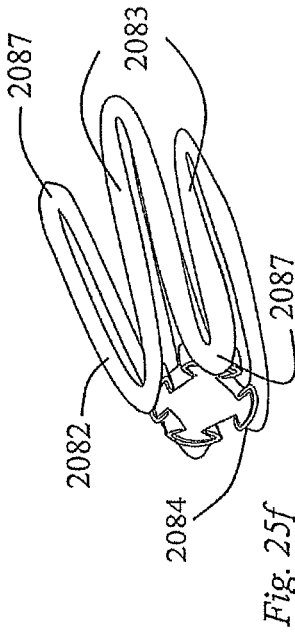


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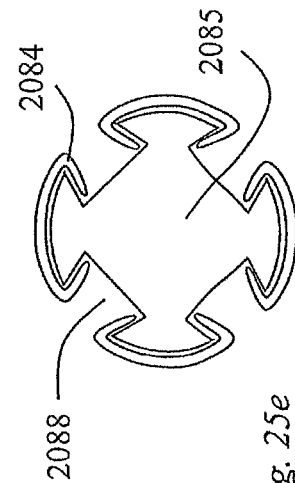


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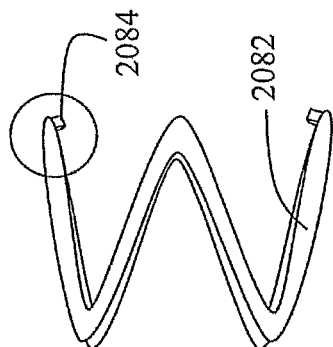


Fig. 25g

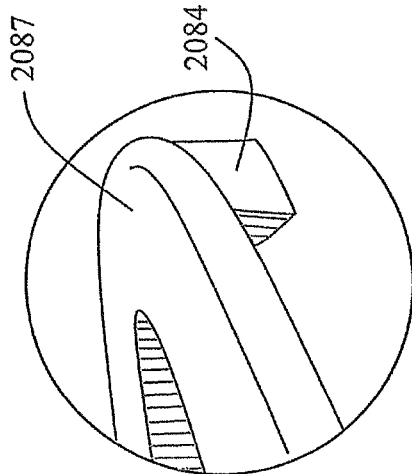


Fig. 25h

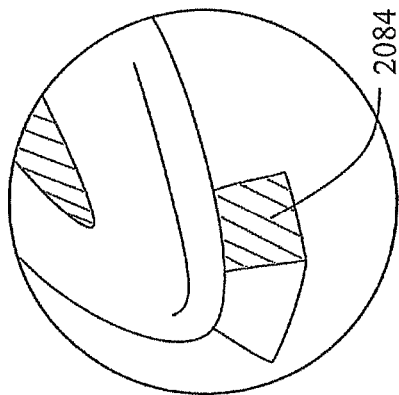


Fig. 25i

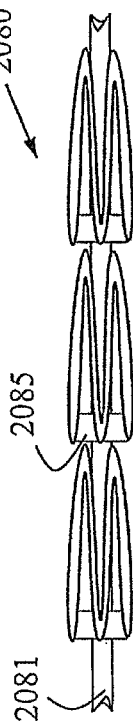


Fig. 25j

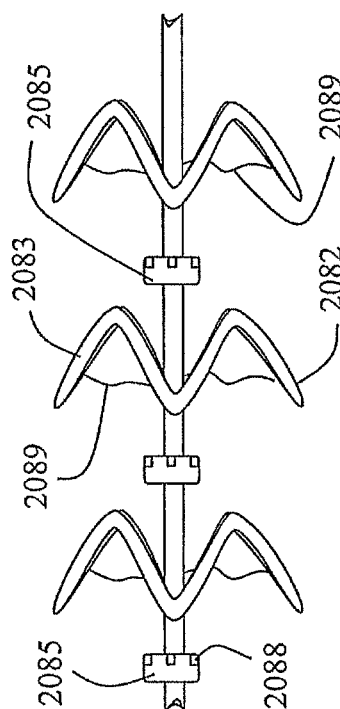


Fig. 25k



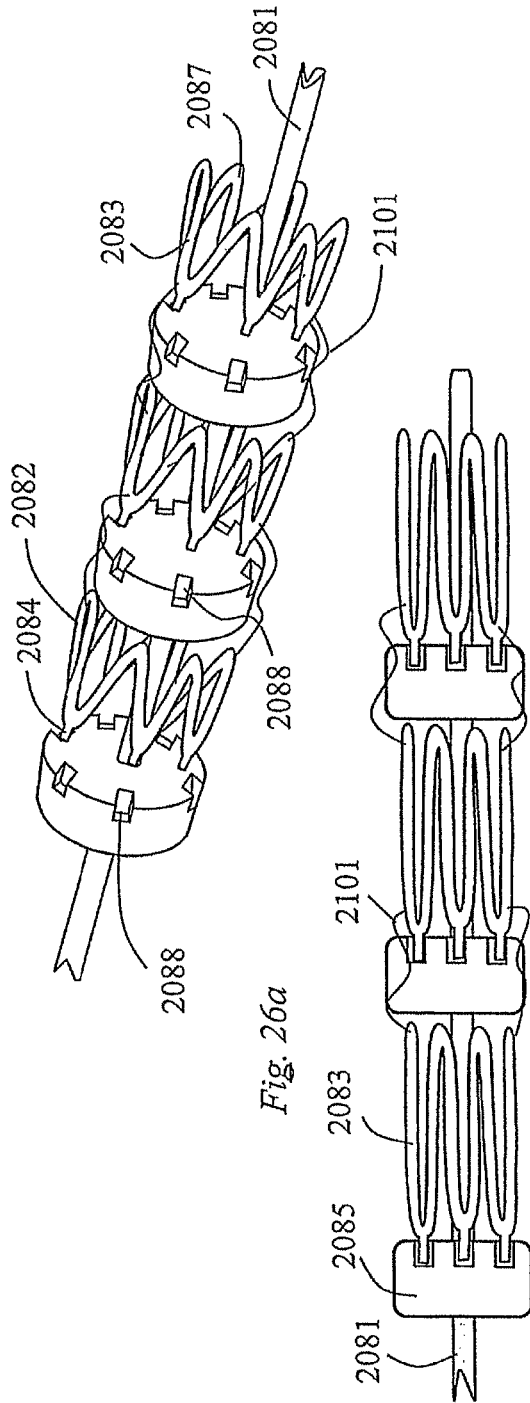


Fig. 26a

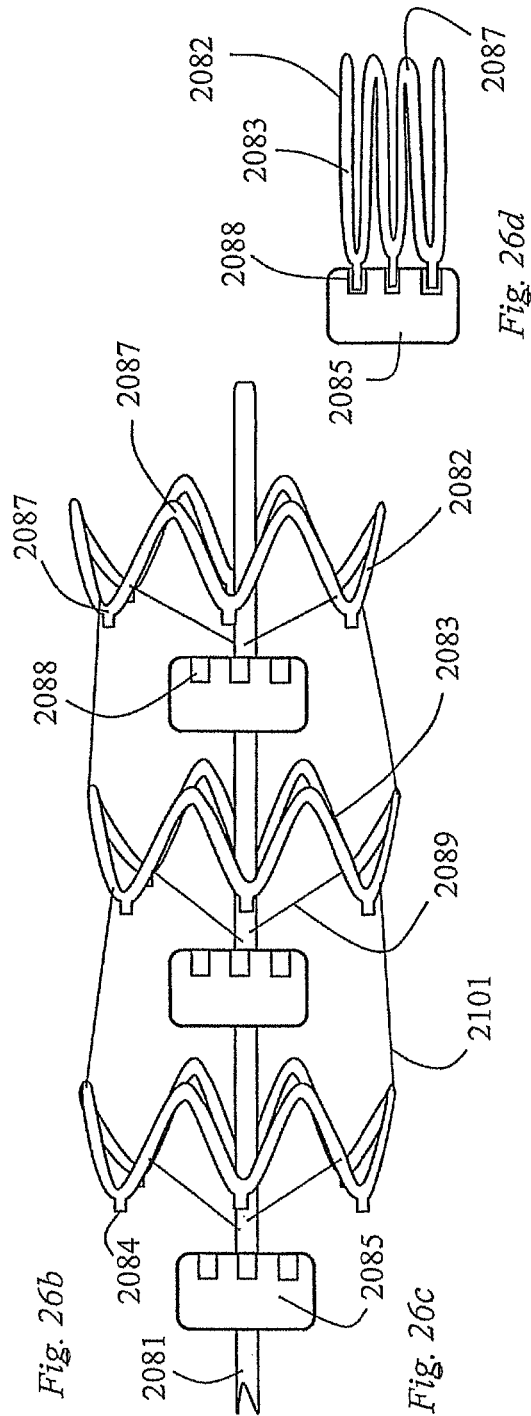


Fig. 26b

Fig. 26c

Fig. 26d

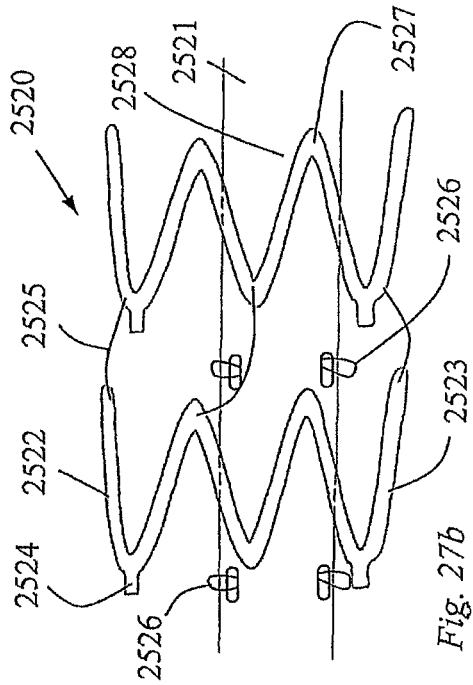


Fig. 27a

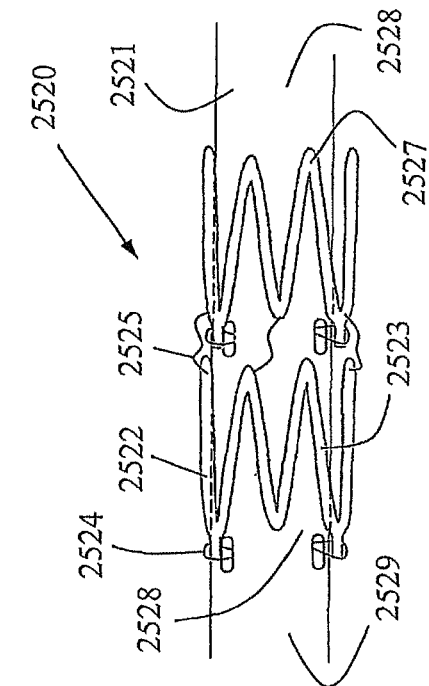


Fig. 27b

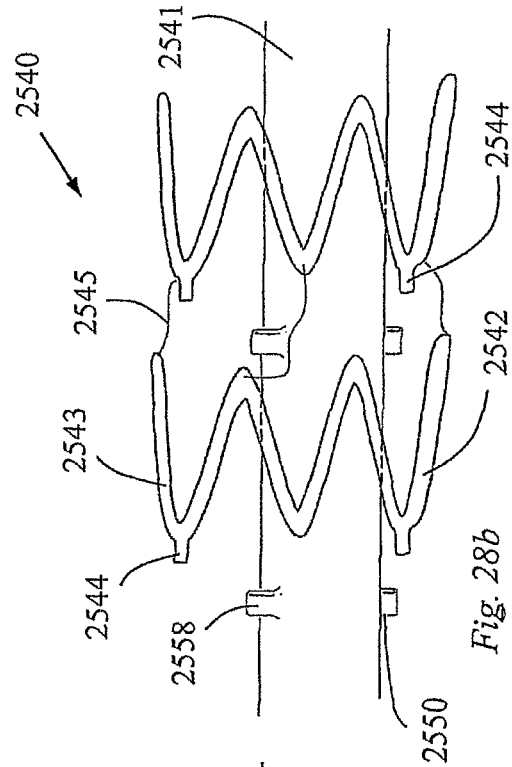


Fig. 28a

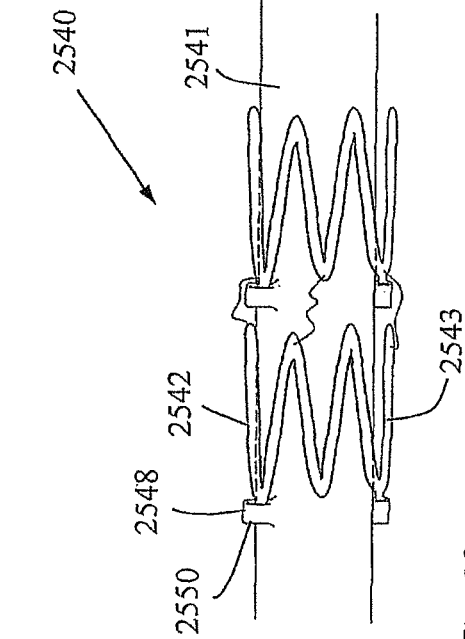
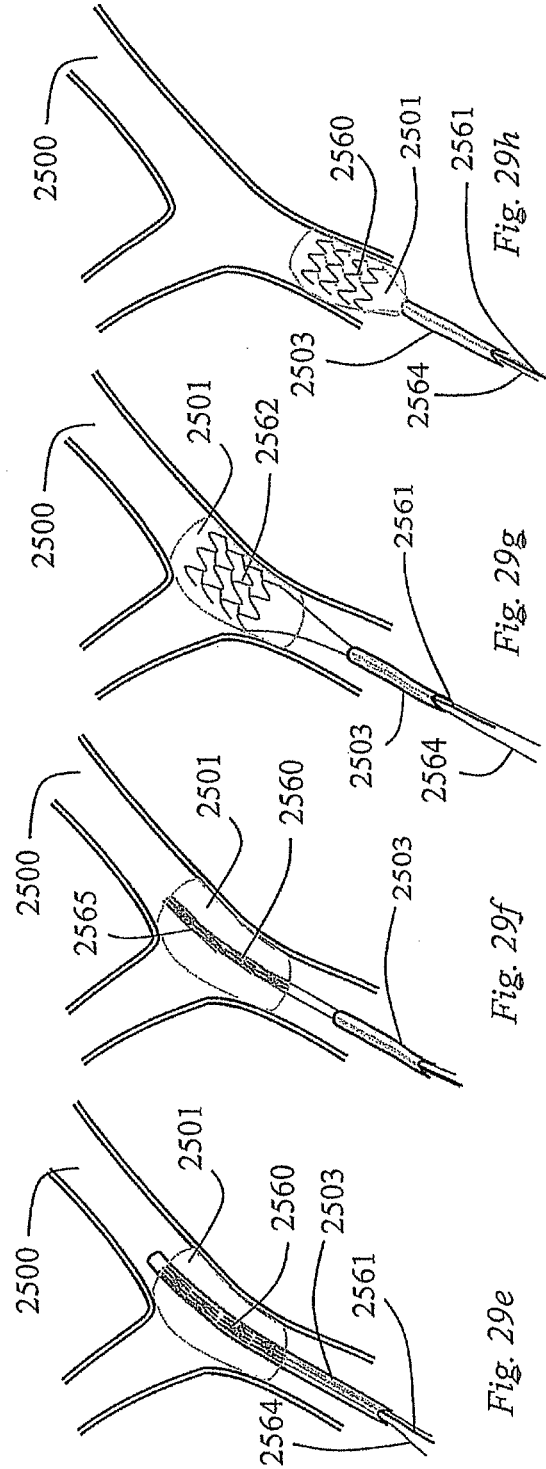
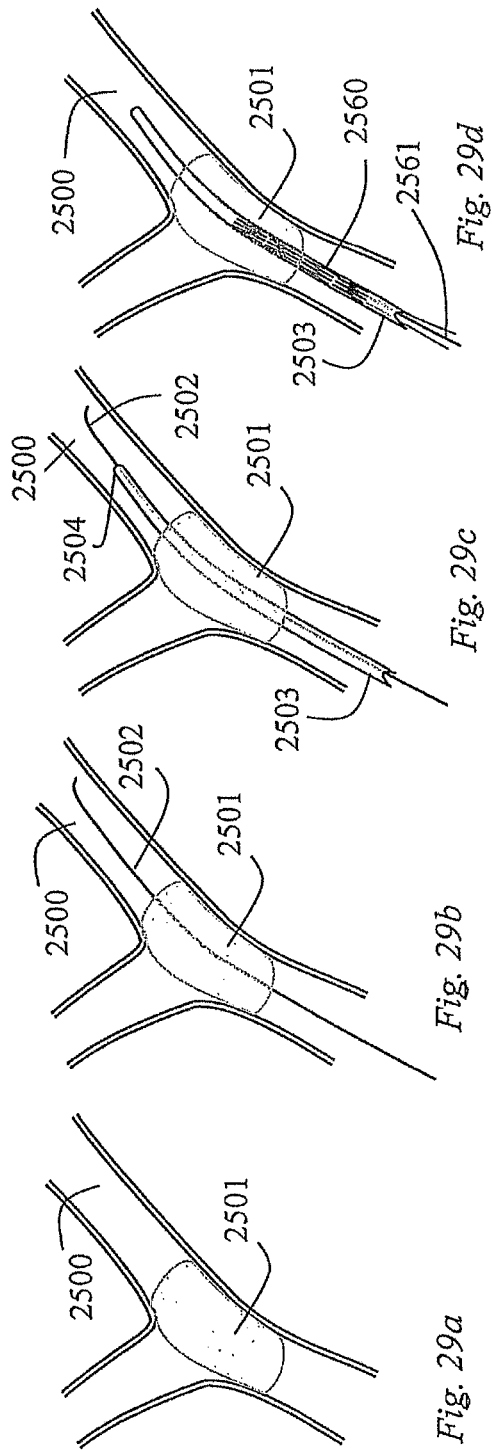
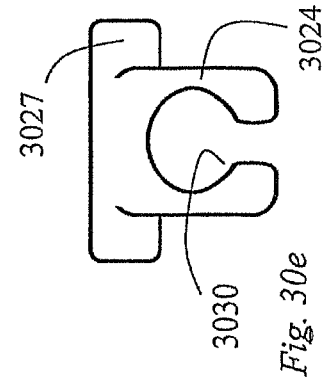
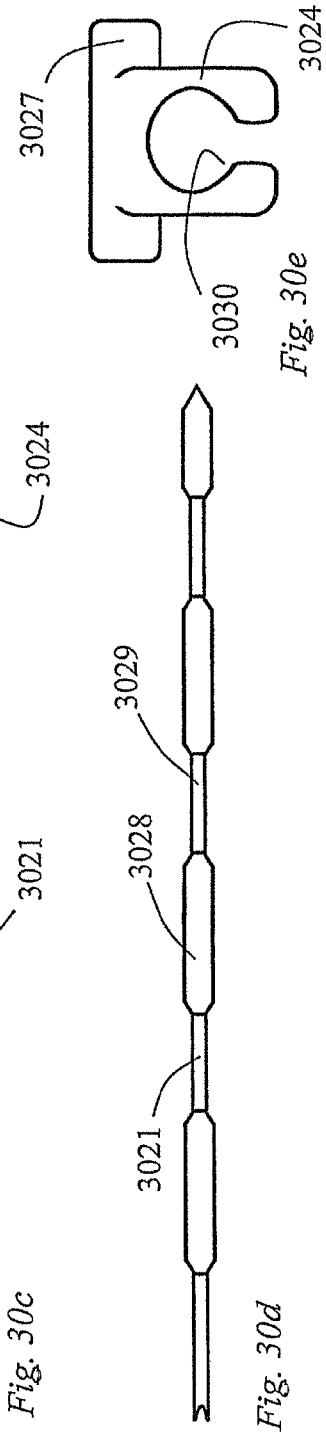
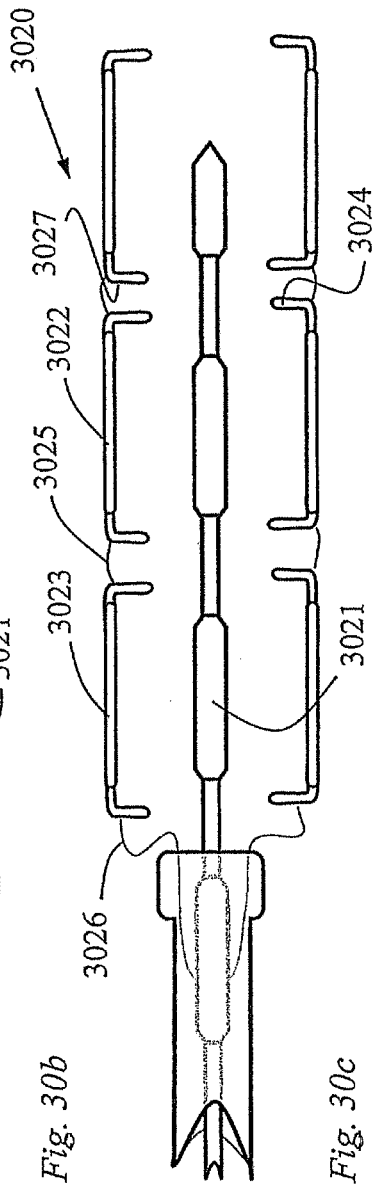
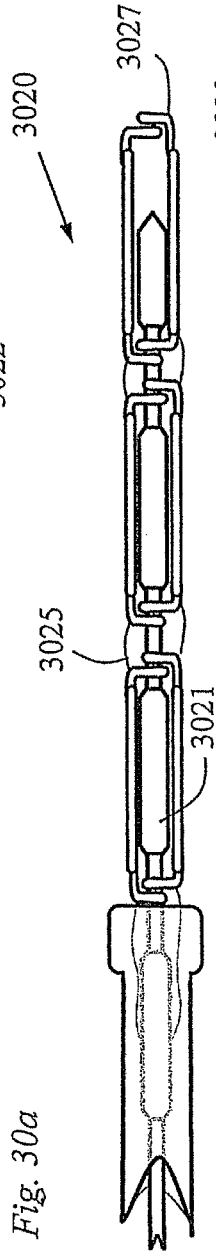
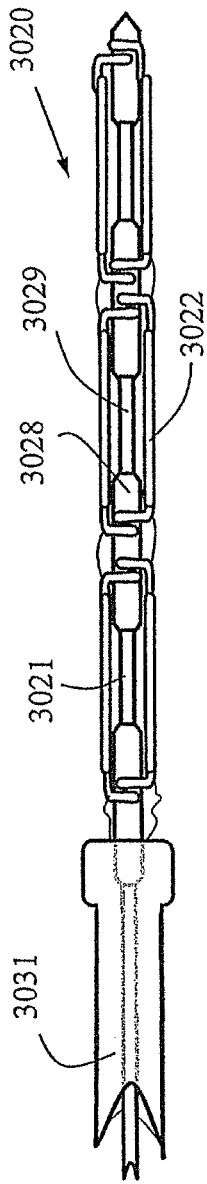
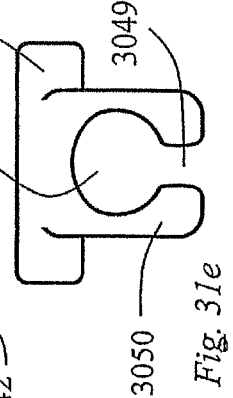
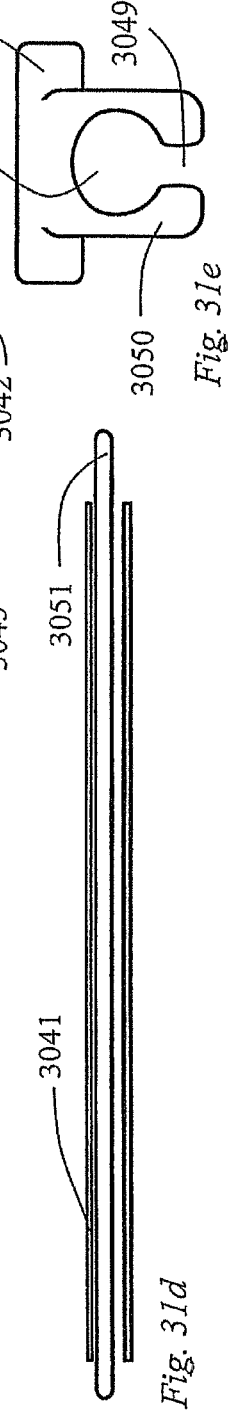
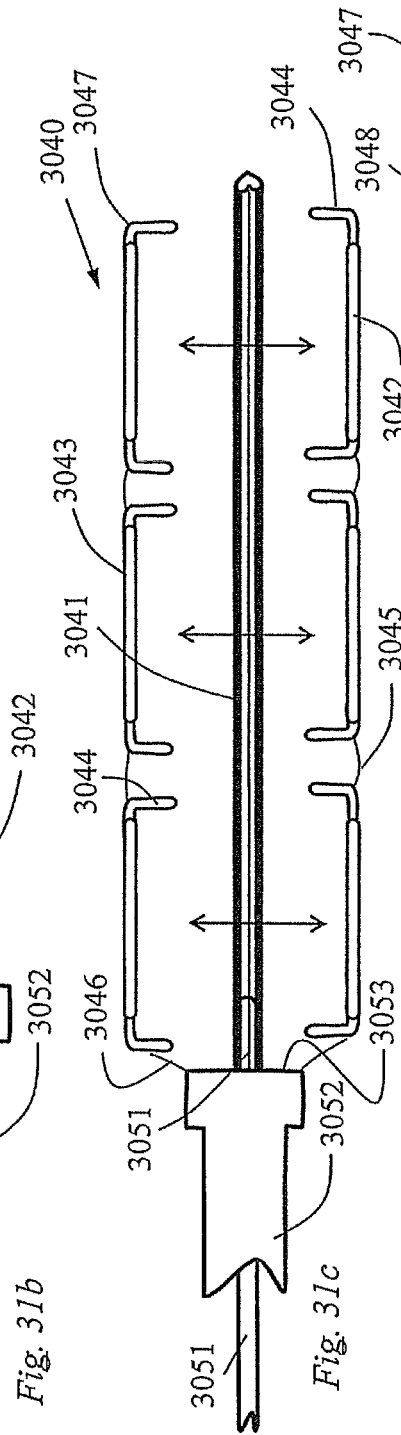
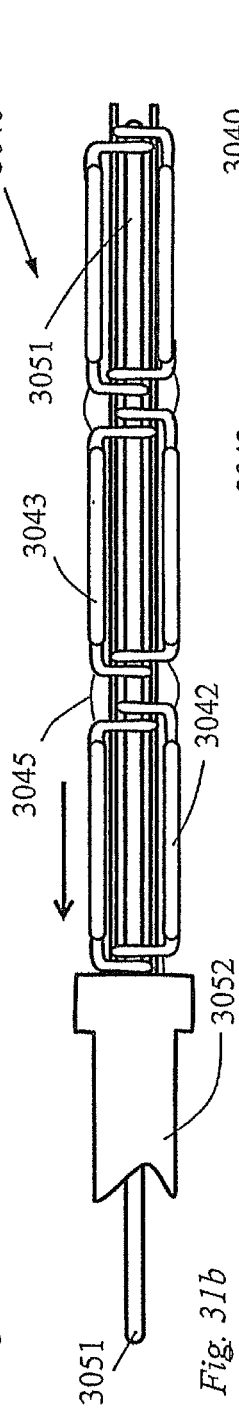
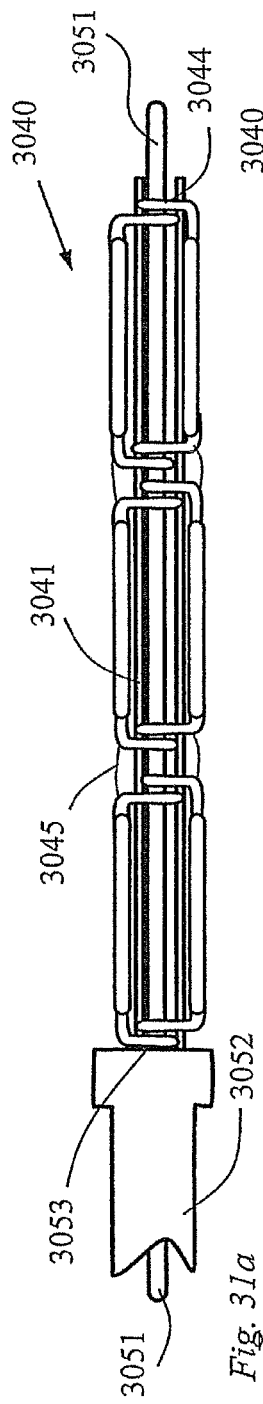


Fig. 28b







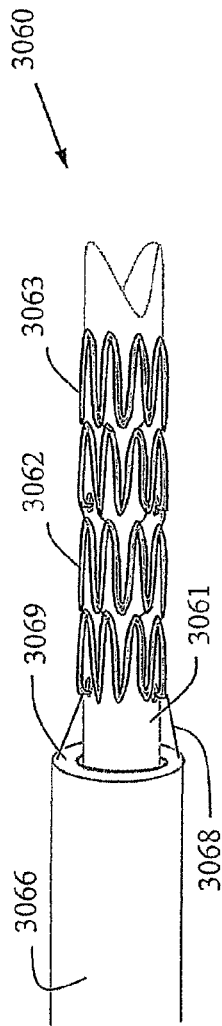


Fig. 32a

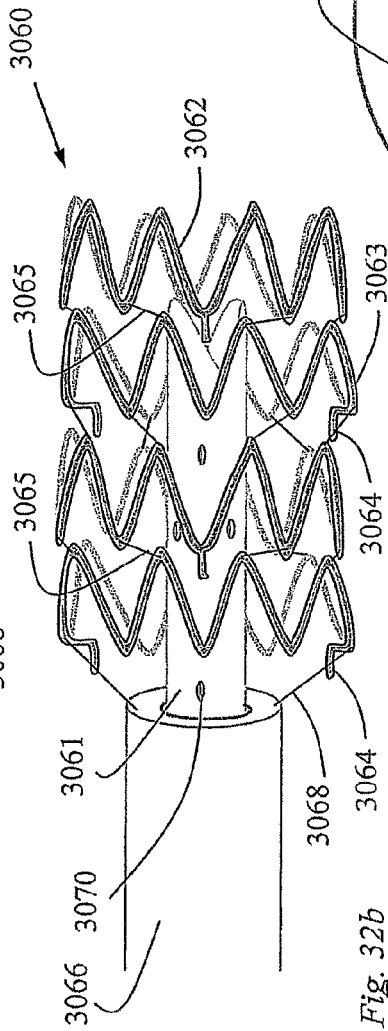


Fig. 32b

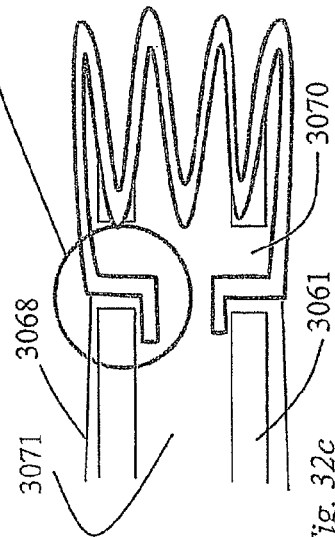


Fig. 32c

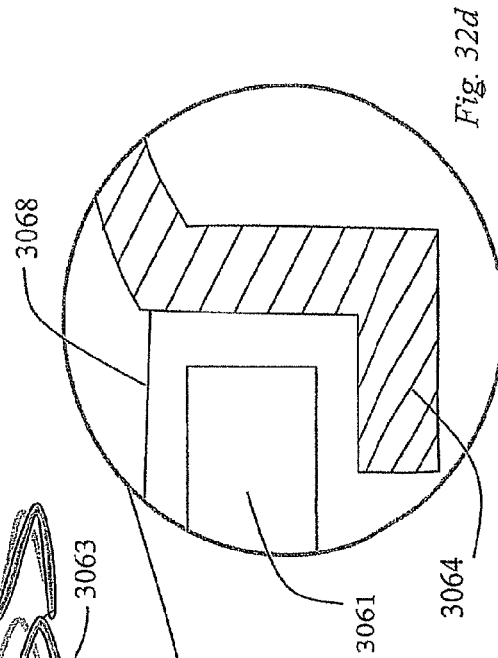
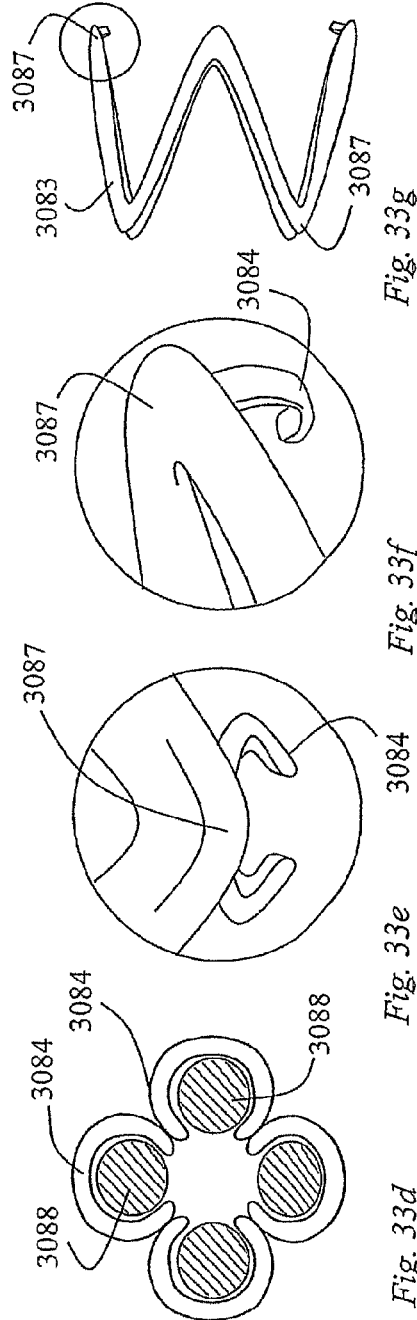
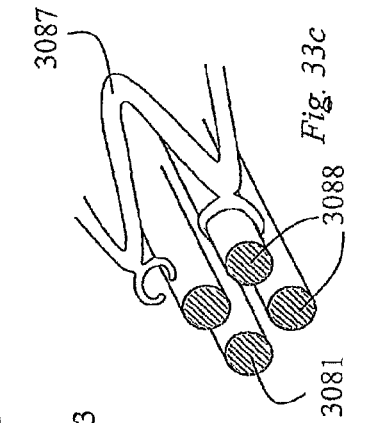
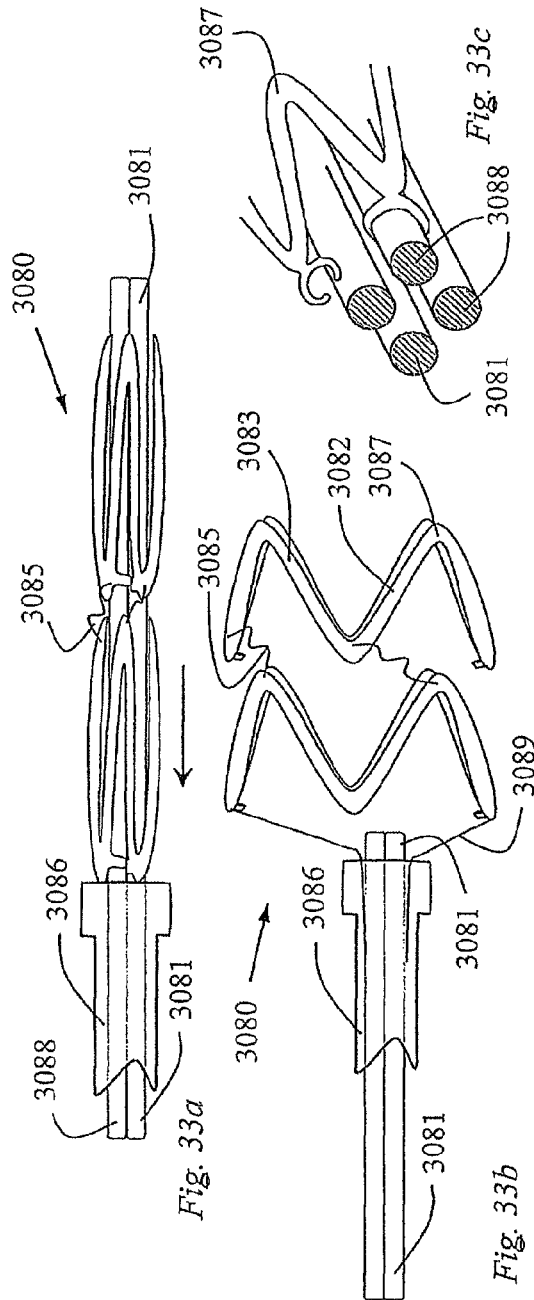


Fig. 32d



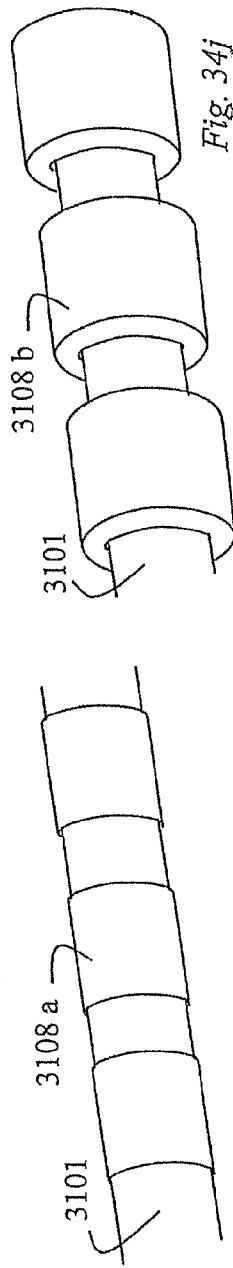


Fig. 34j

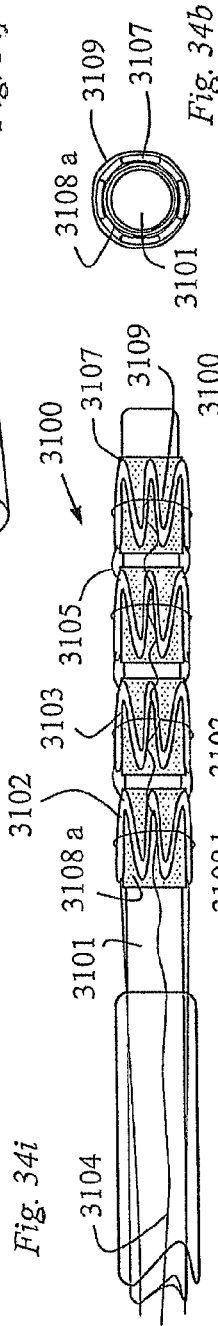


Fig. 34a

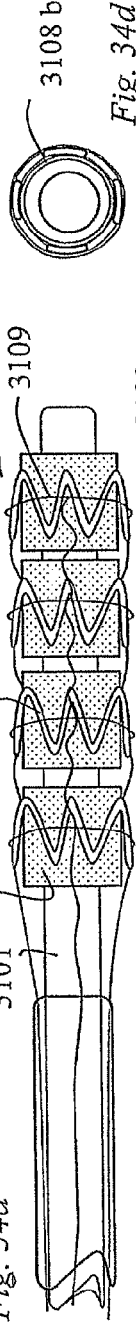


Fig. 34c

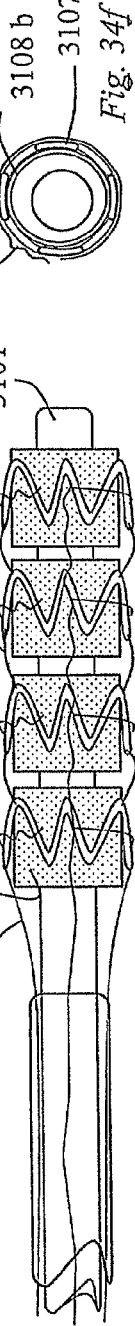


Fig. 34e

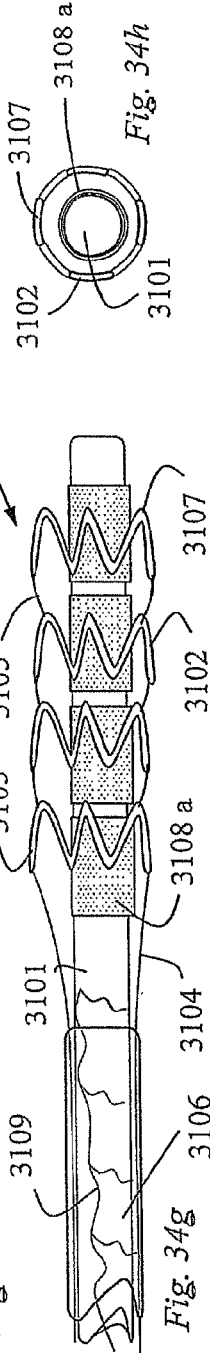


Fig. 34g

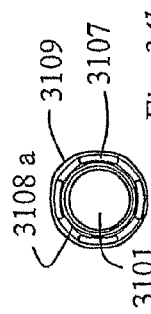


Fig. 34b

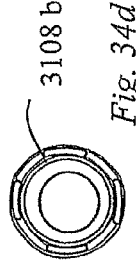


Fig. 34d

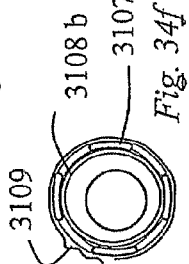


Fig. 34f

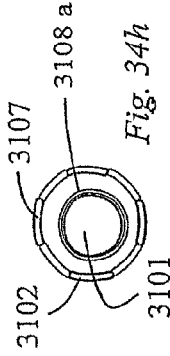
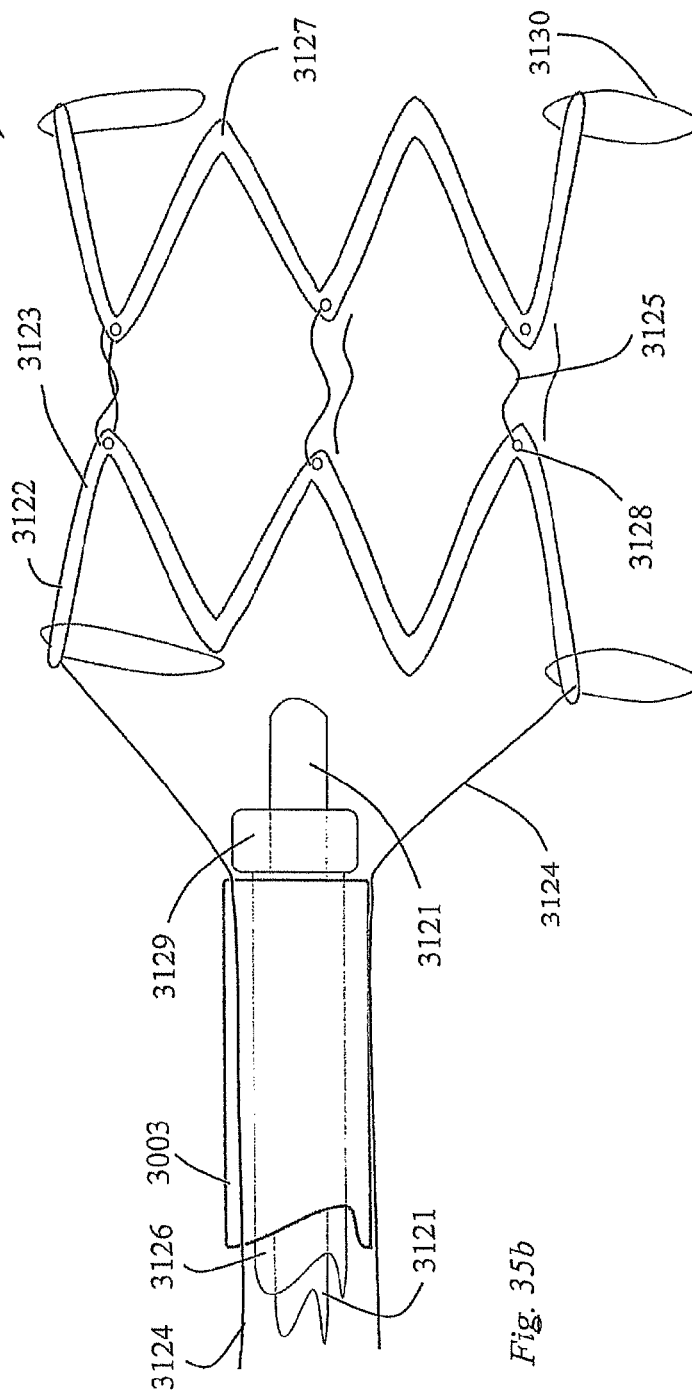
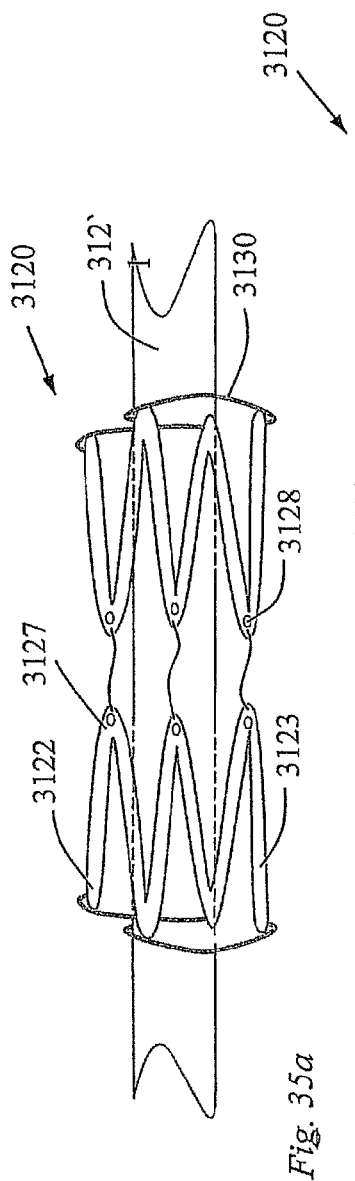
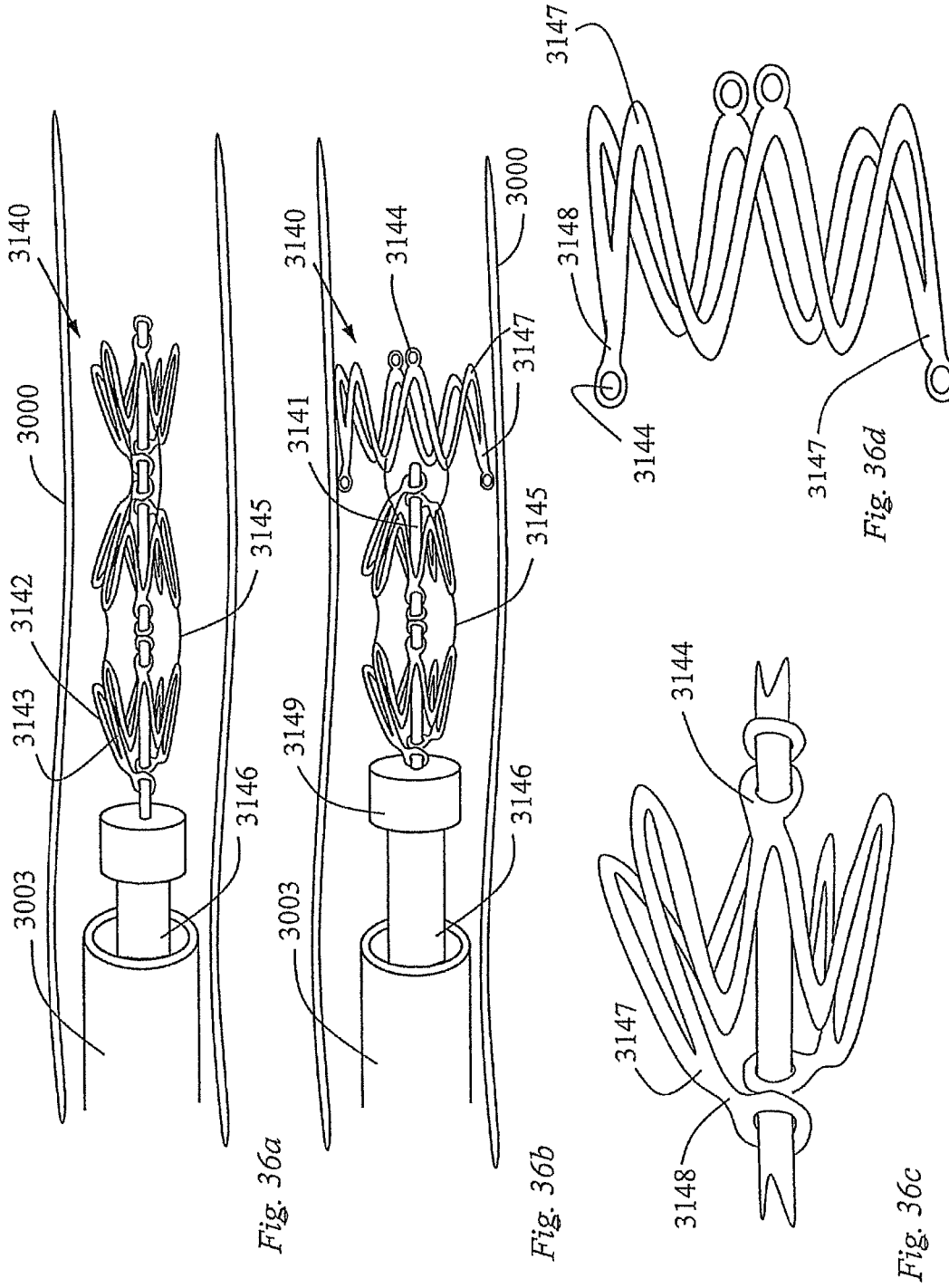


Fig. 34h







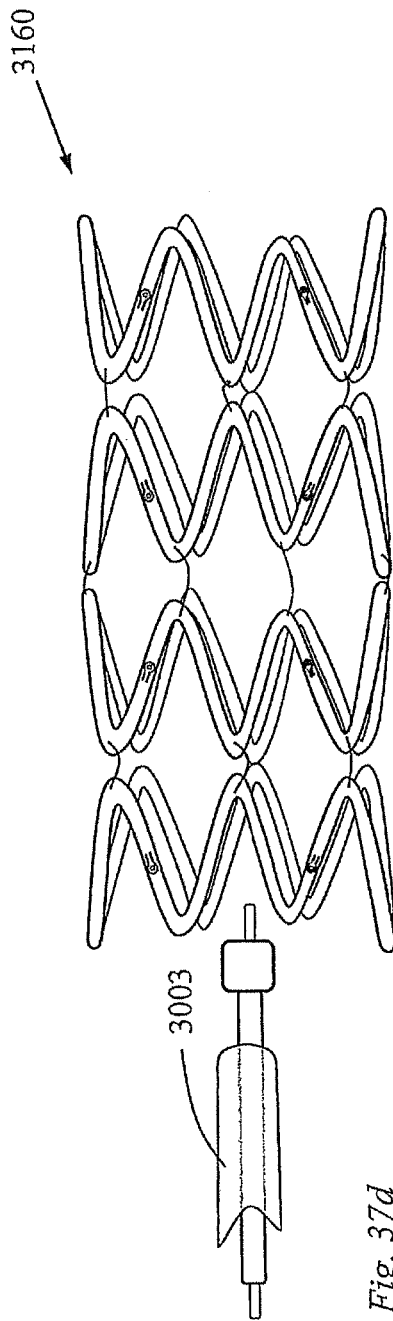
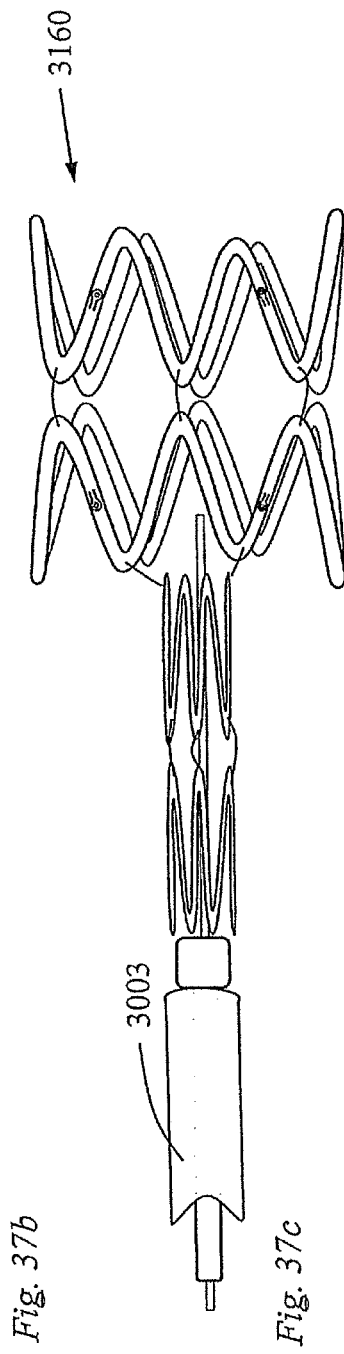
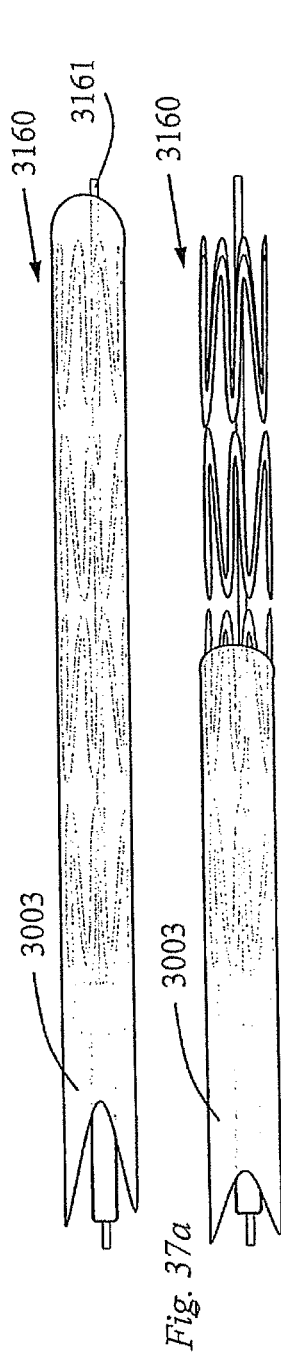
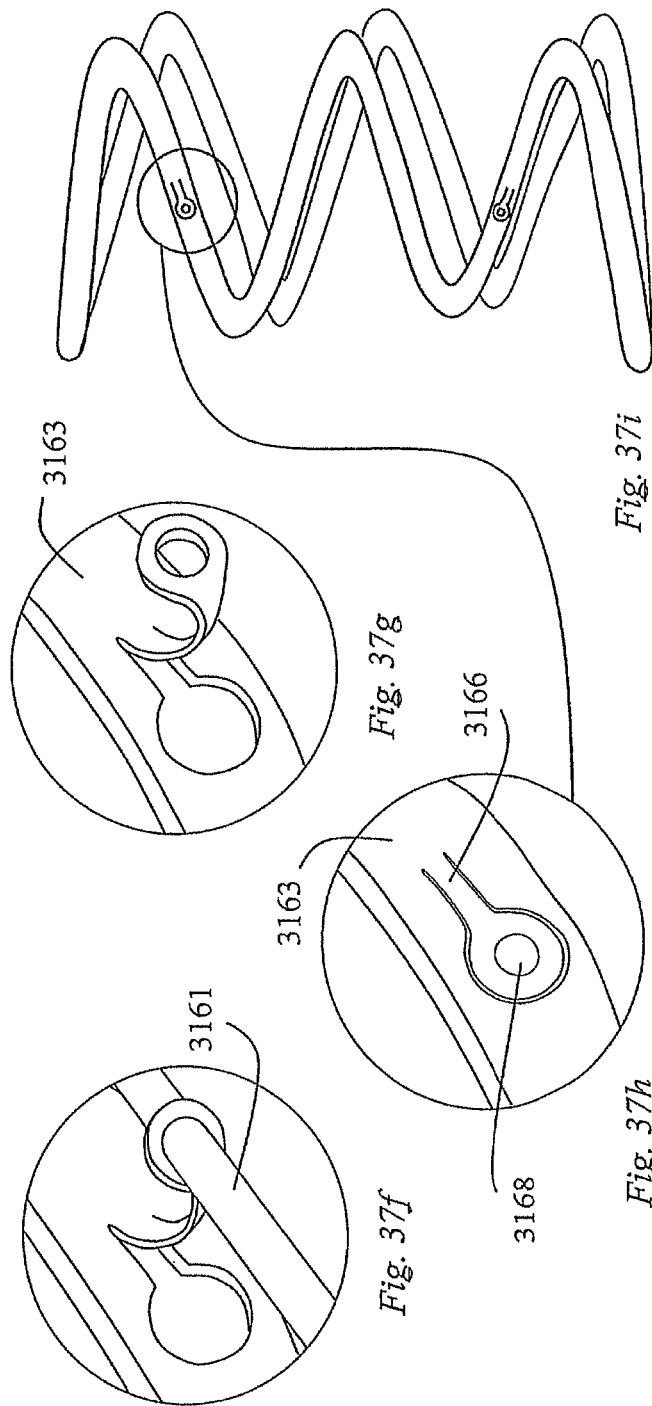
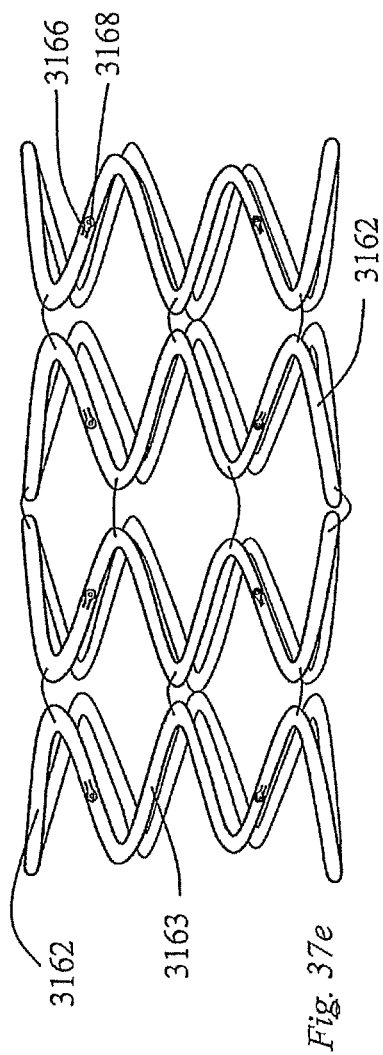
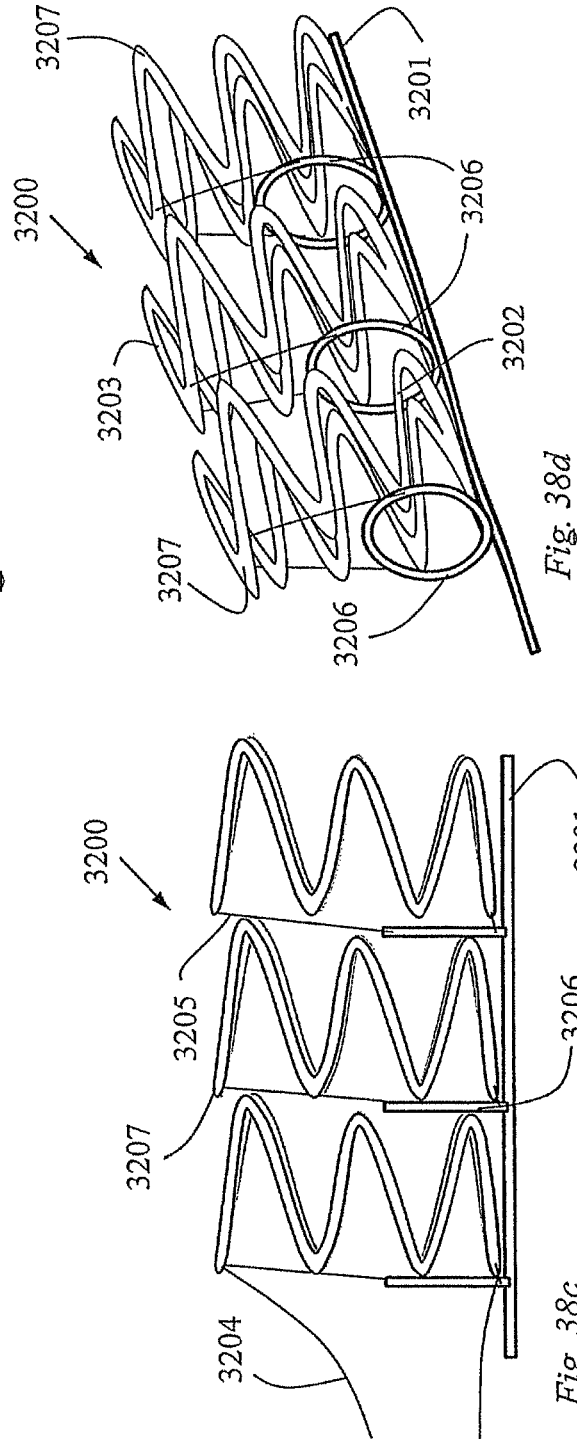
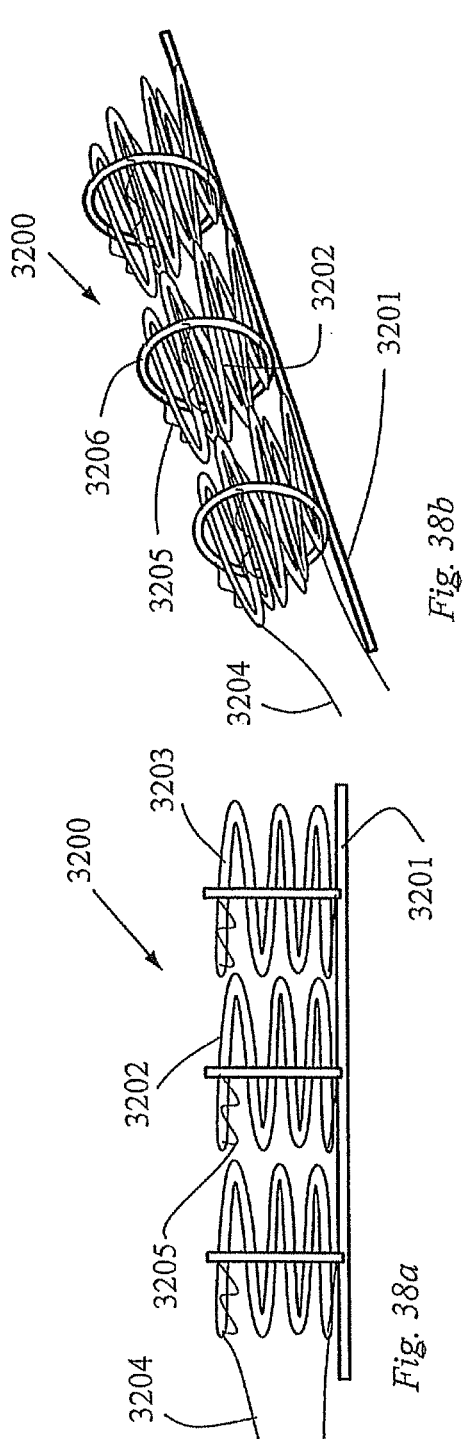


Fig. 37d





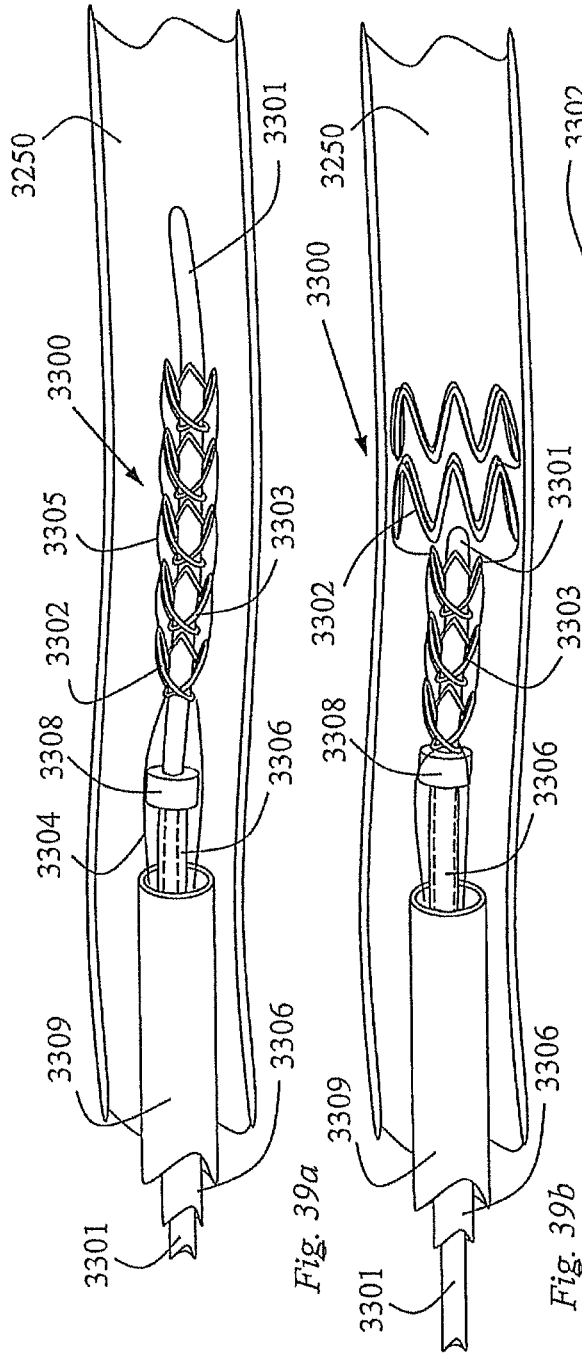


Fig. 39a

Fig. 39b

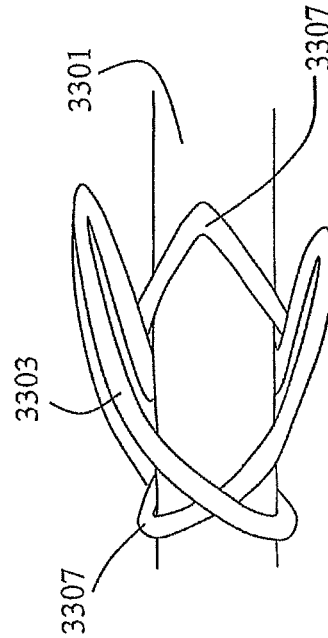


Fig. 39c

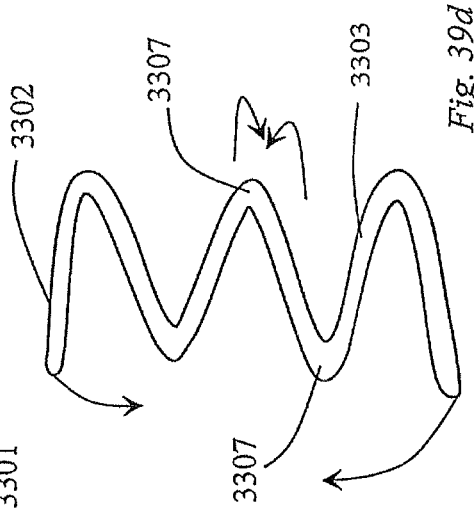
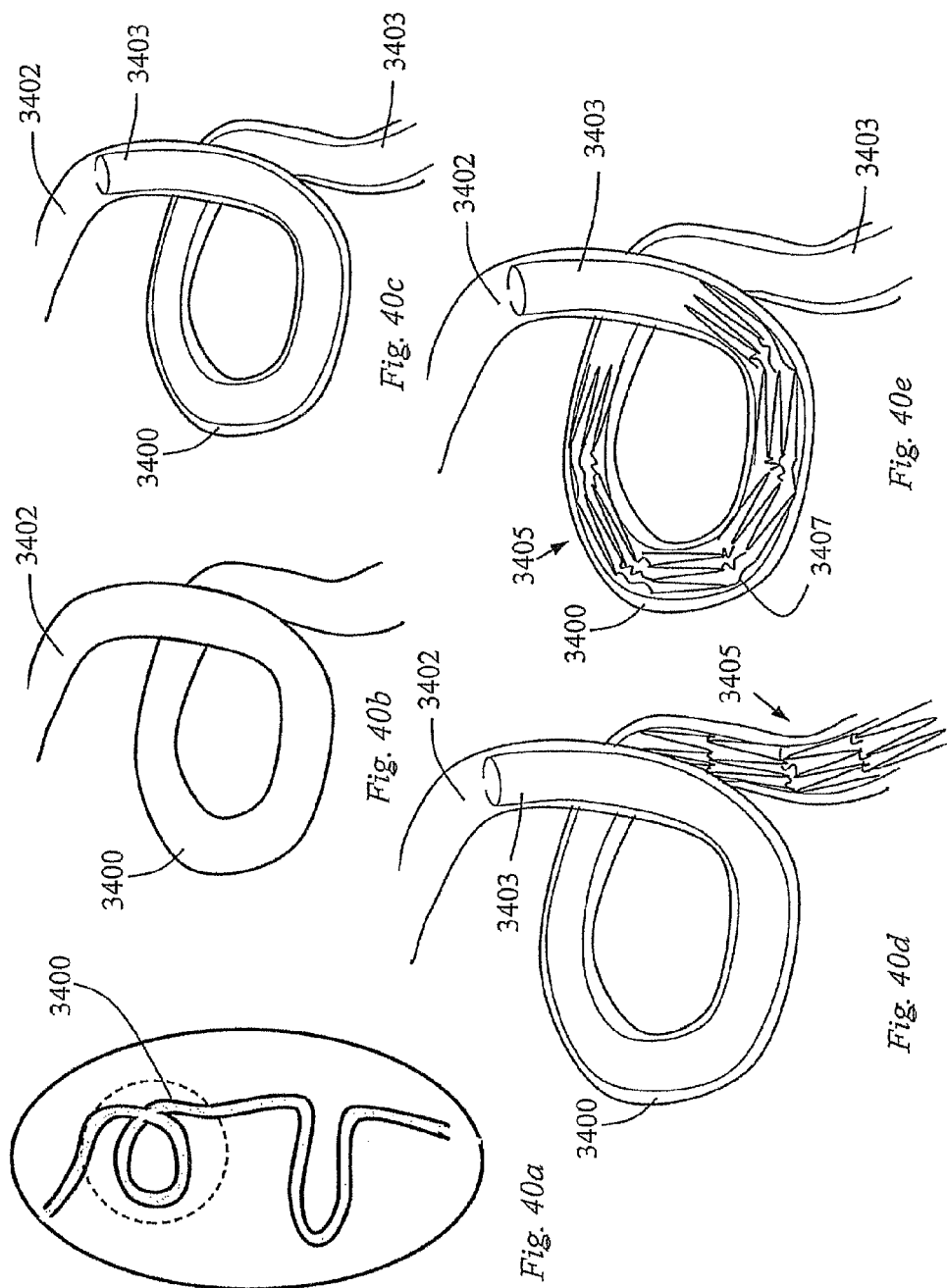
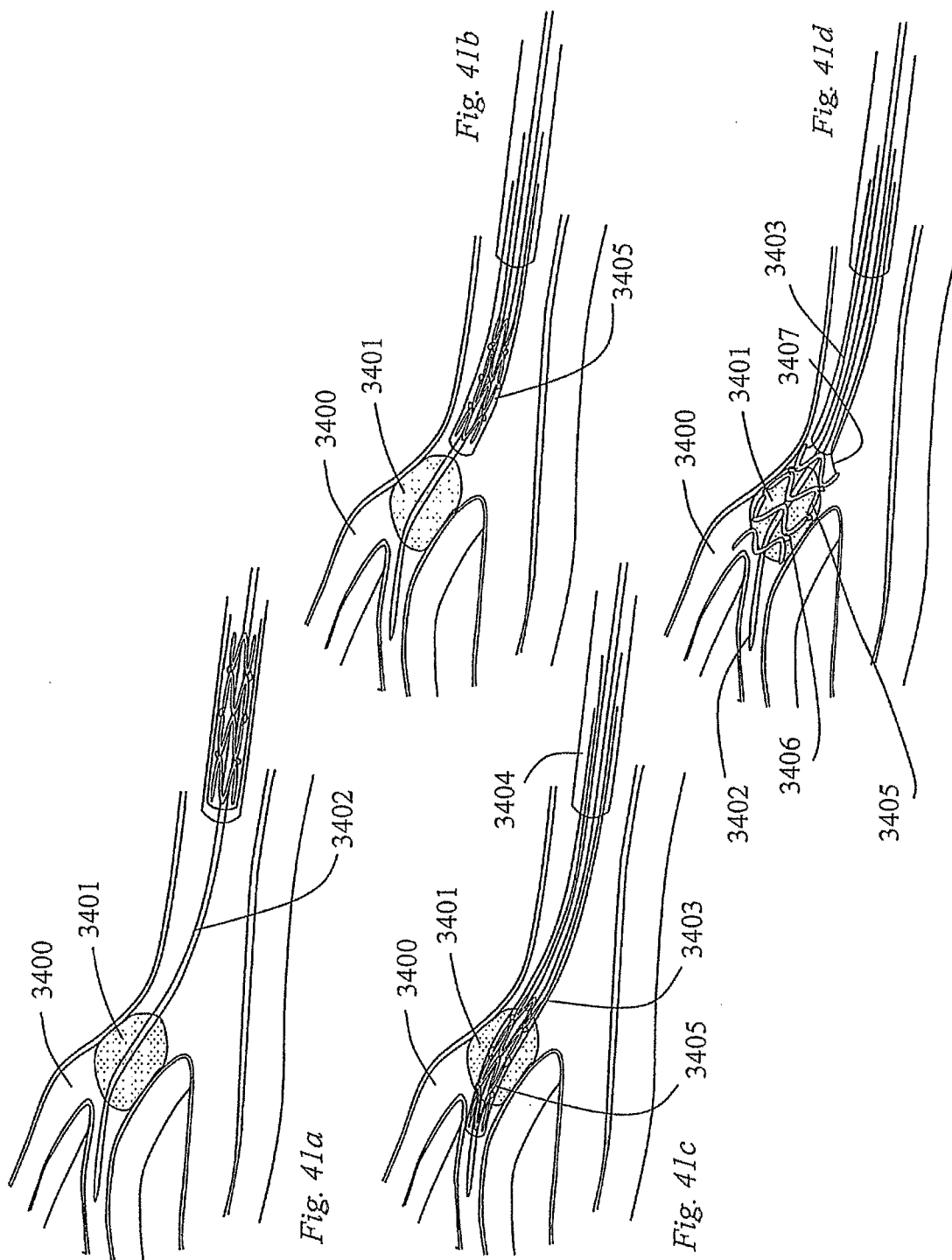
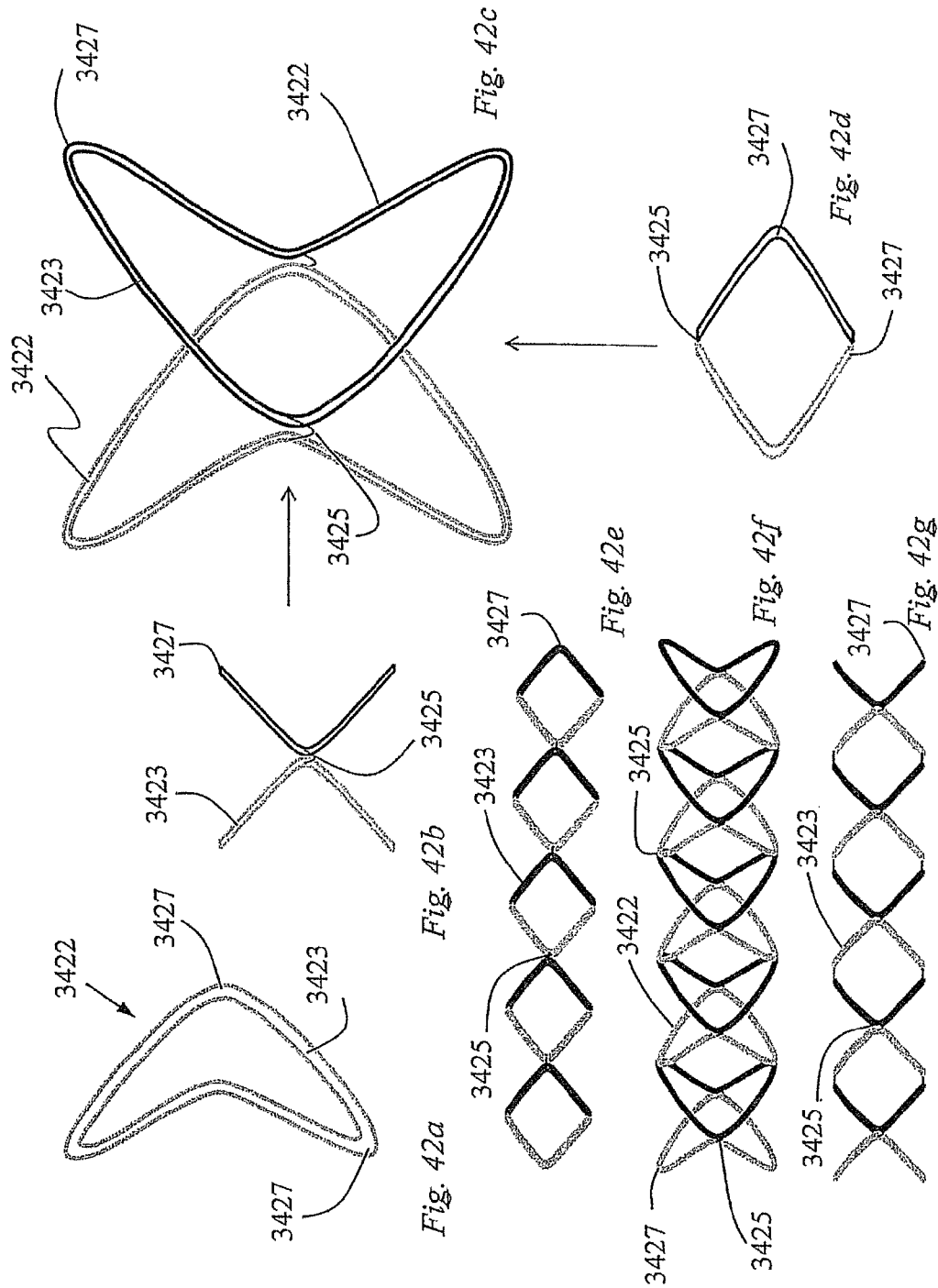


Fig. 39d









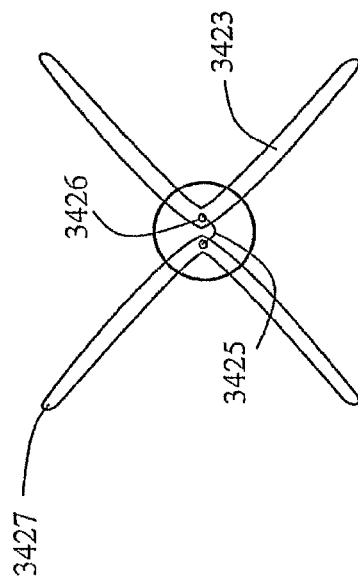


Fig. 43a

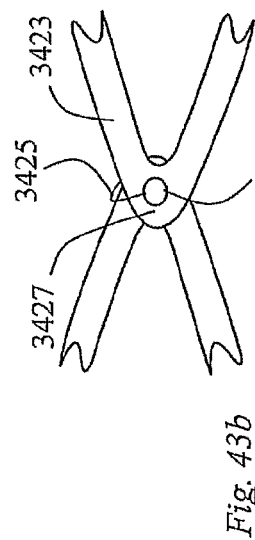


Fig. 43b

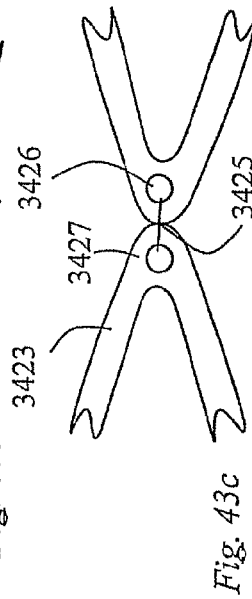


Fig. 43c

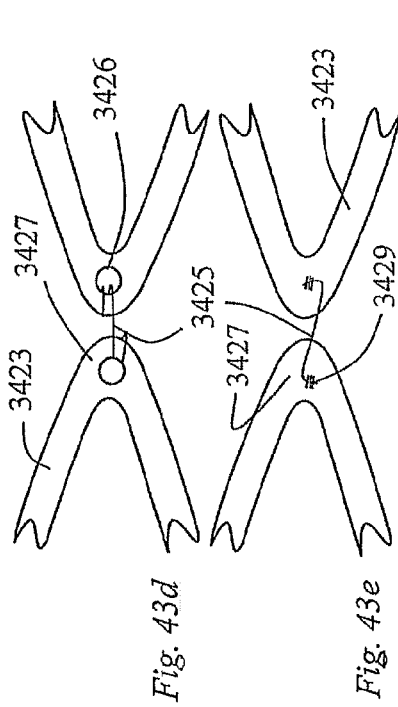


Fig. 43d

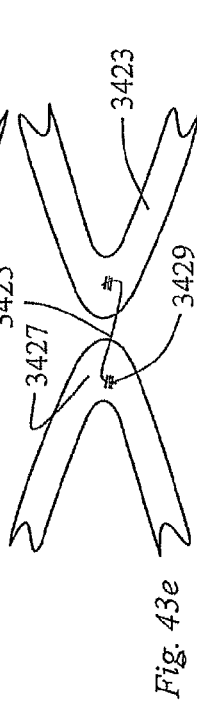


Fig. 43e

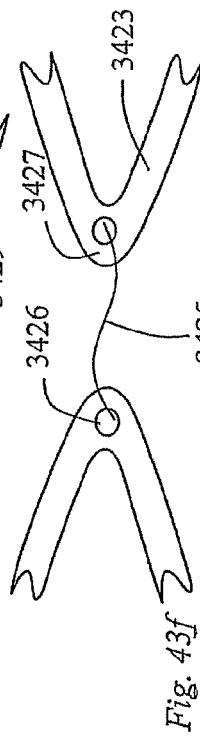


Fig. 43f

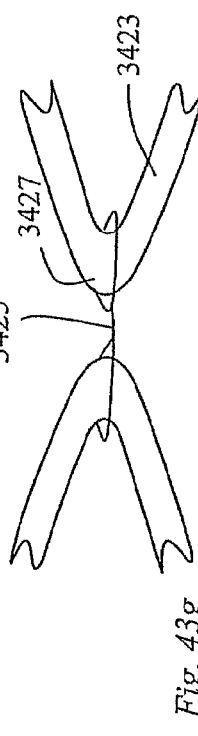


Fig. 43g

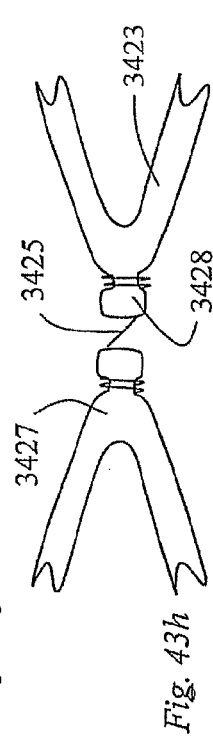


Fig. 43h

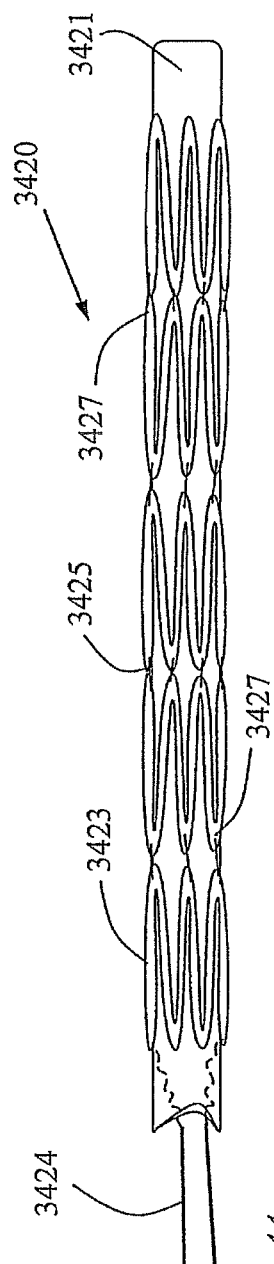


Fig. 44a

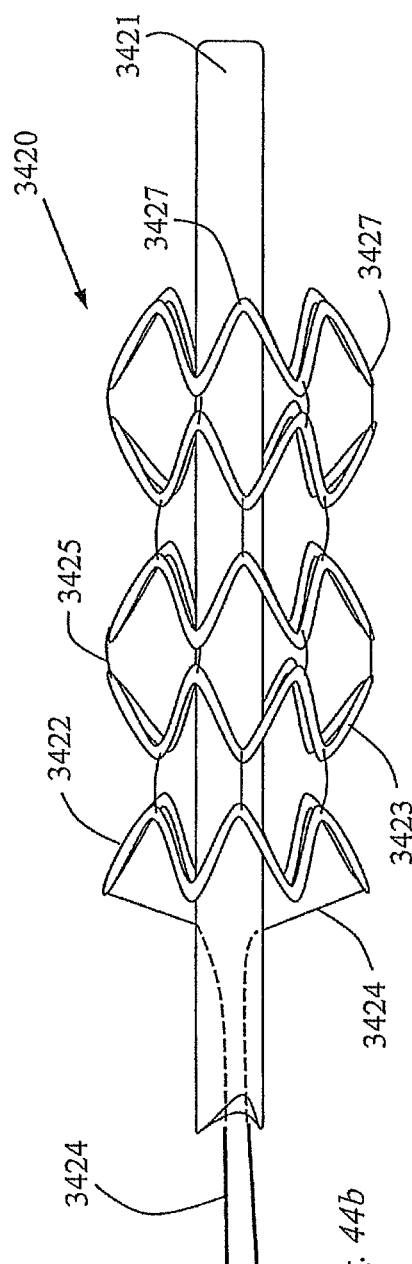


Fig. 44b

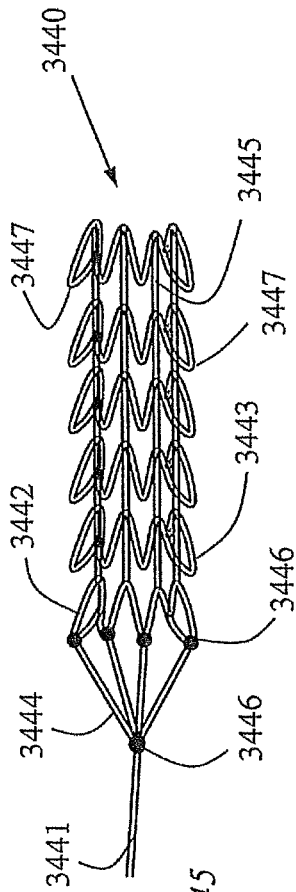


Fig. 45

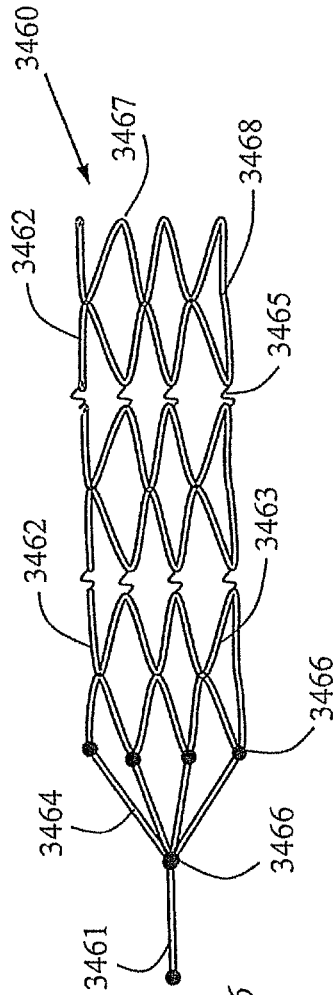


Fig. 46

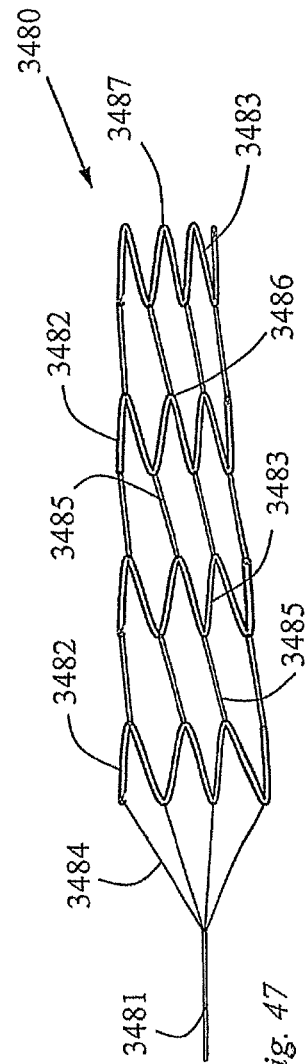
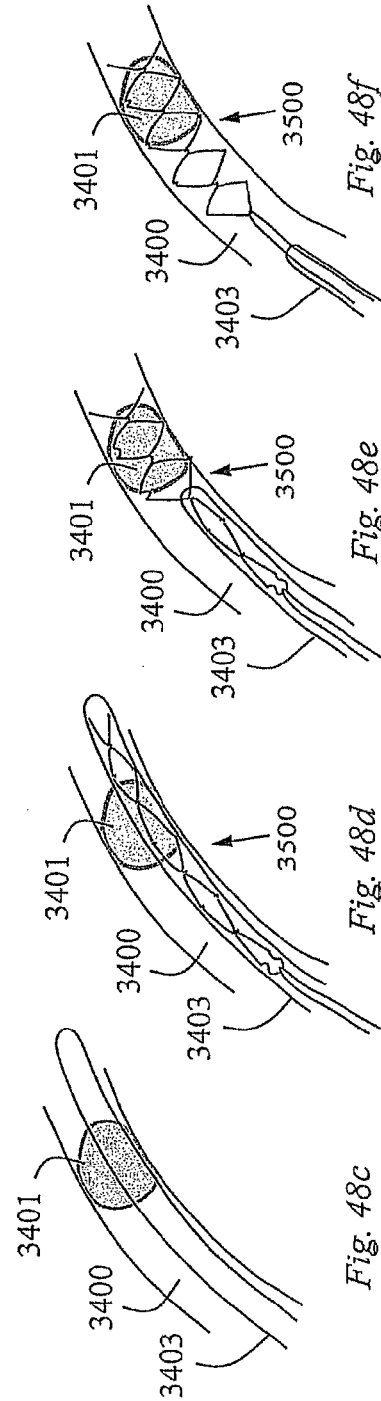
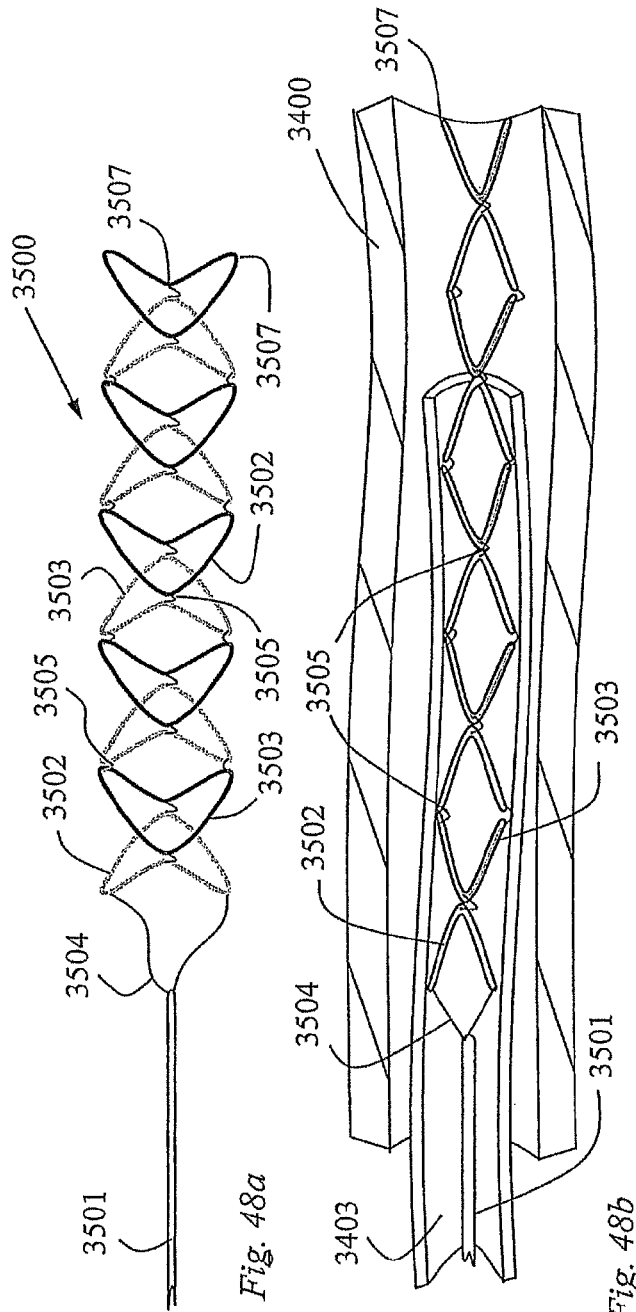
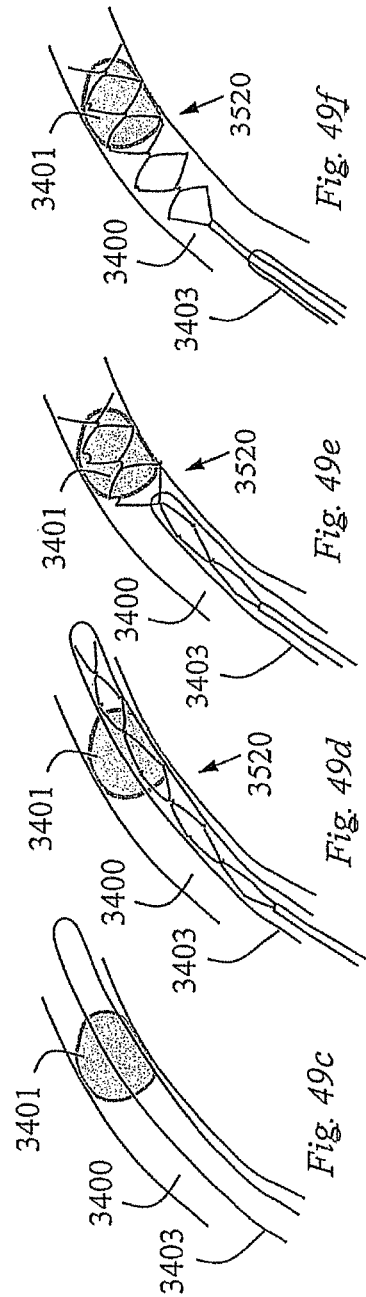
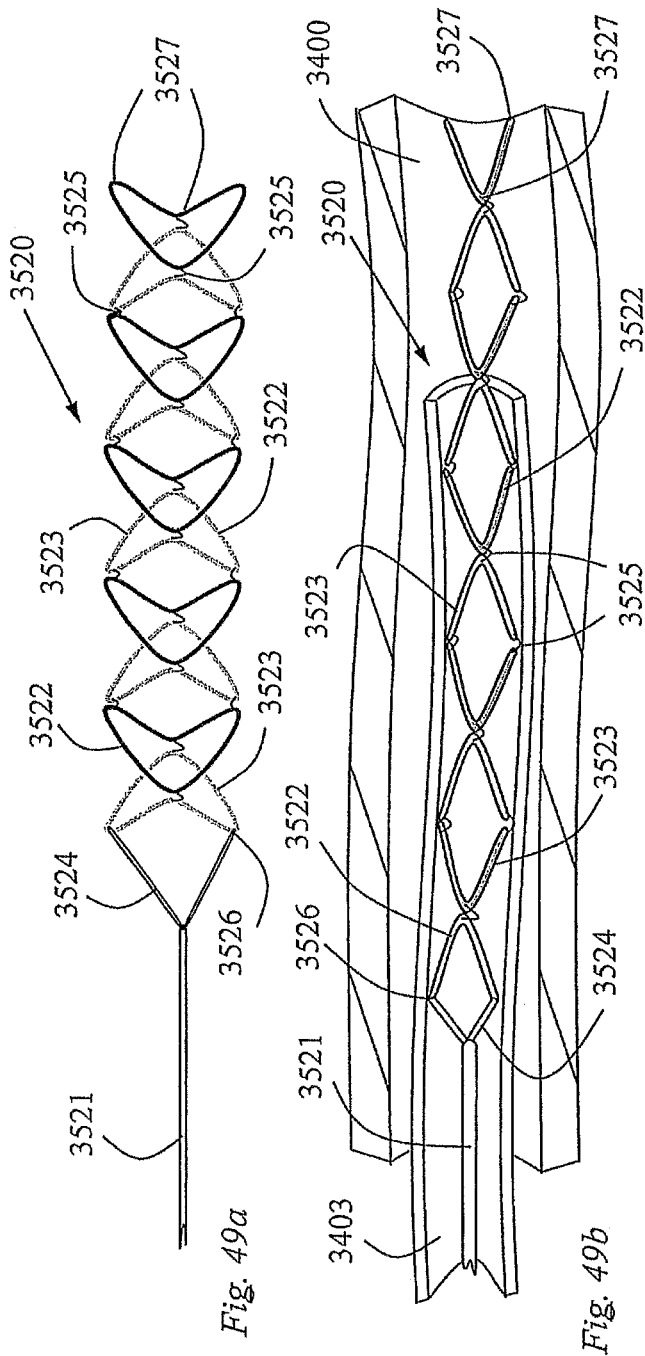
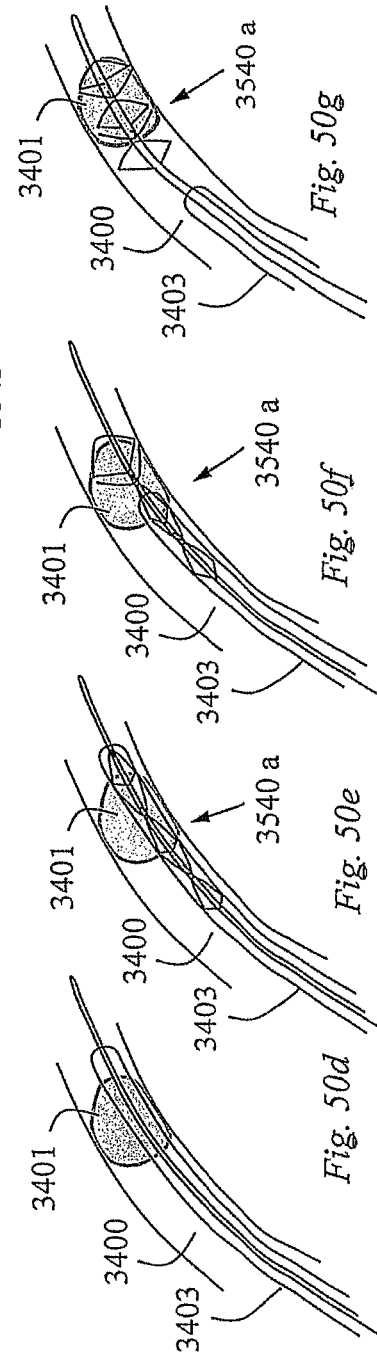
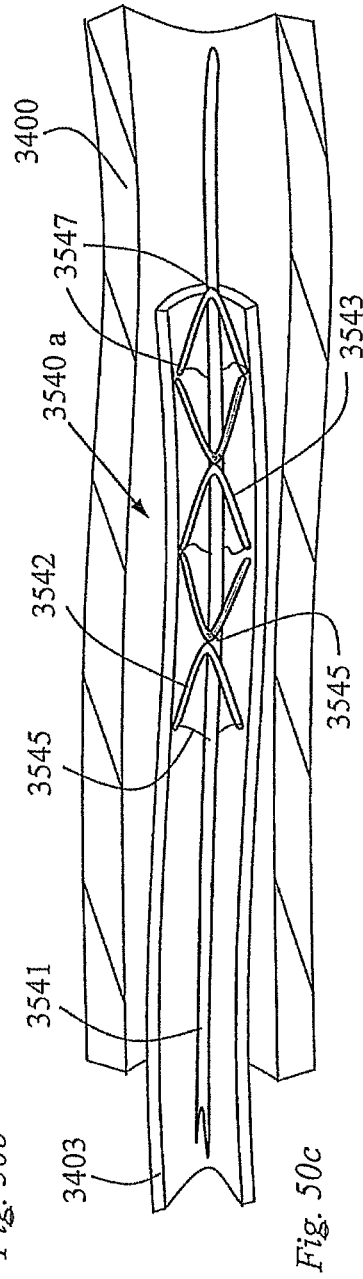
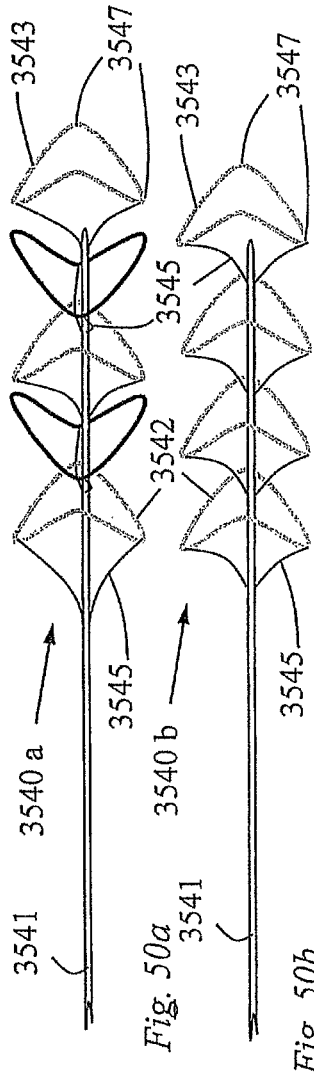
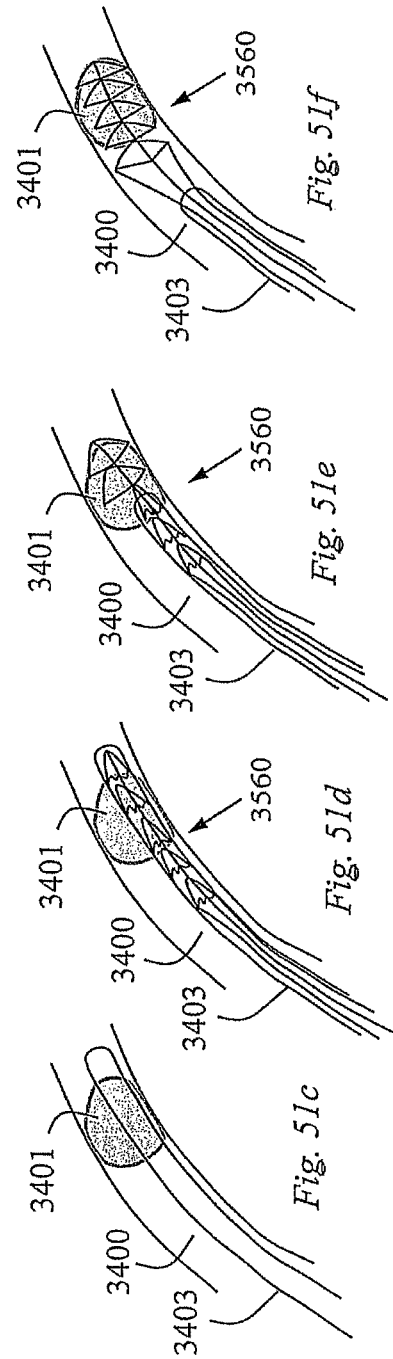
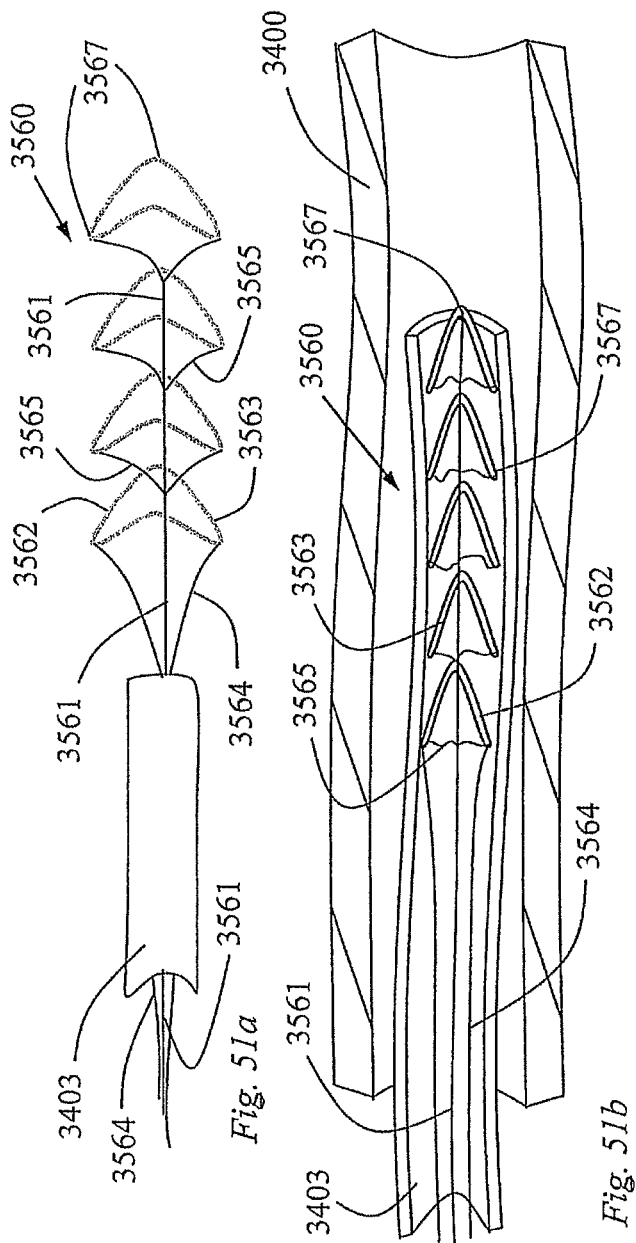


Fig. 47

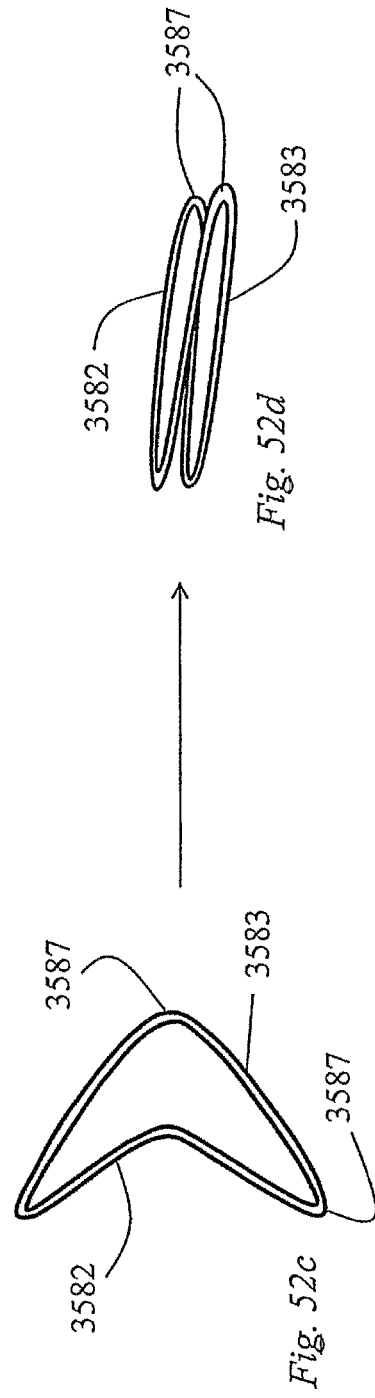
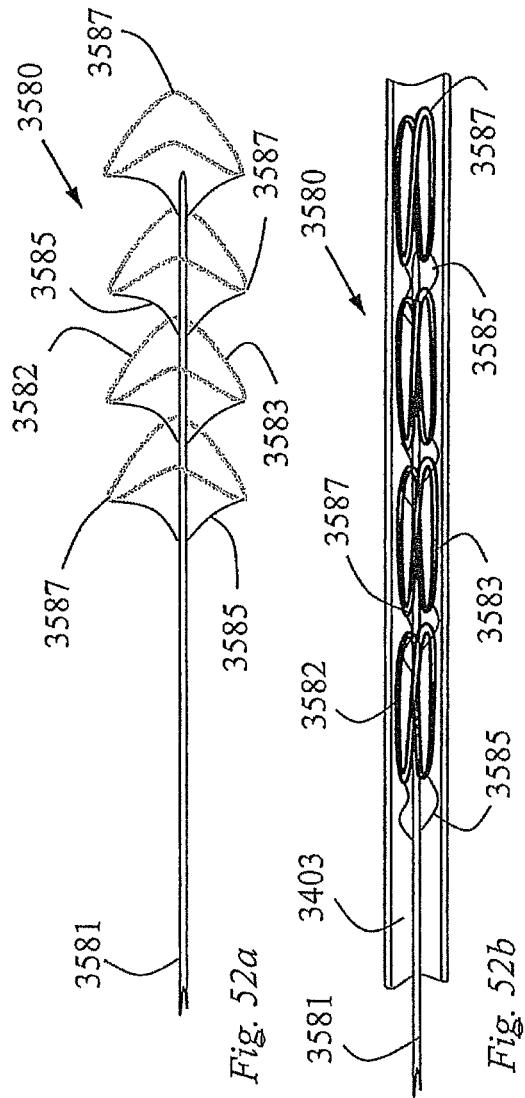


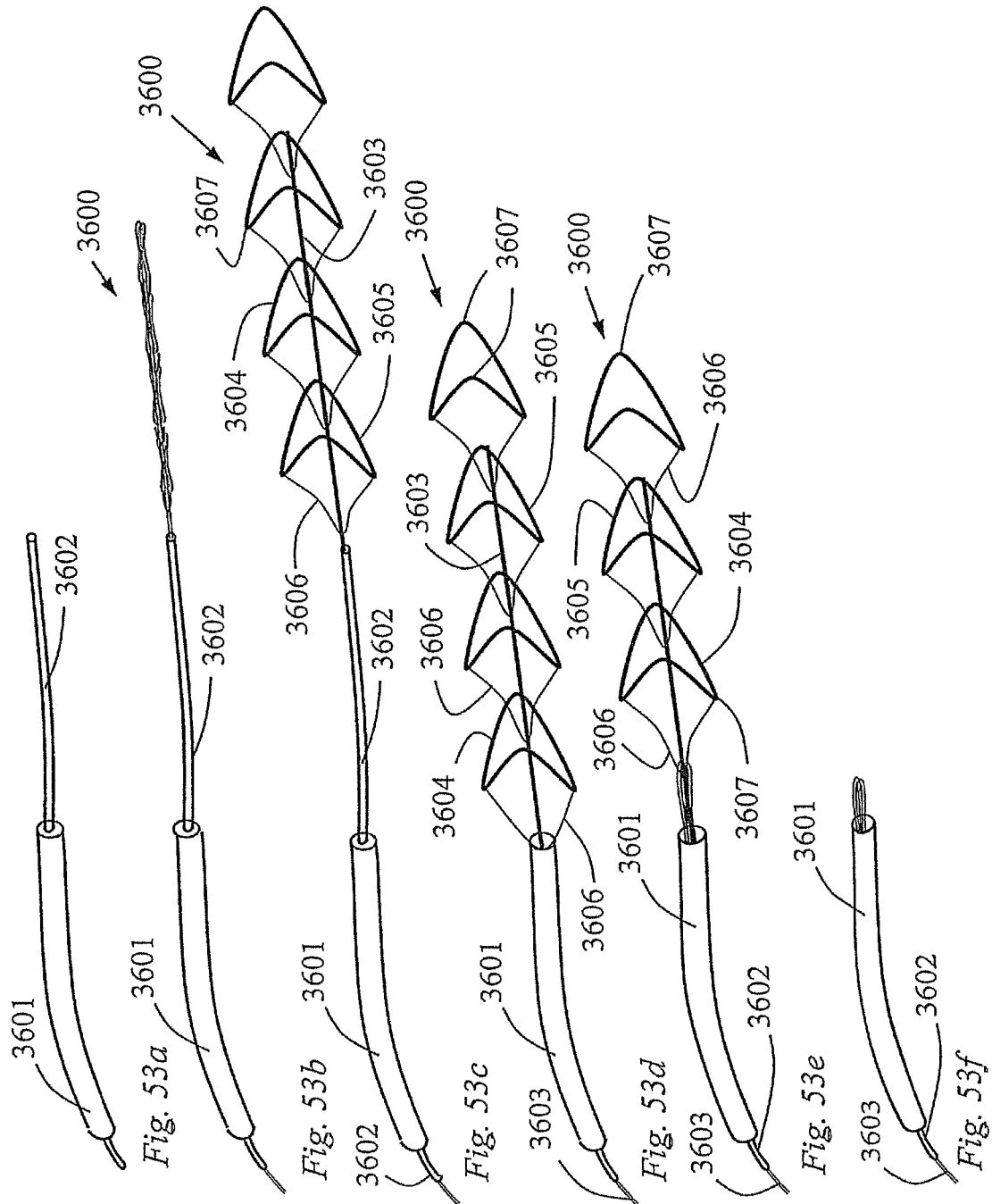


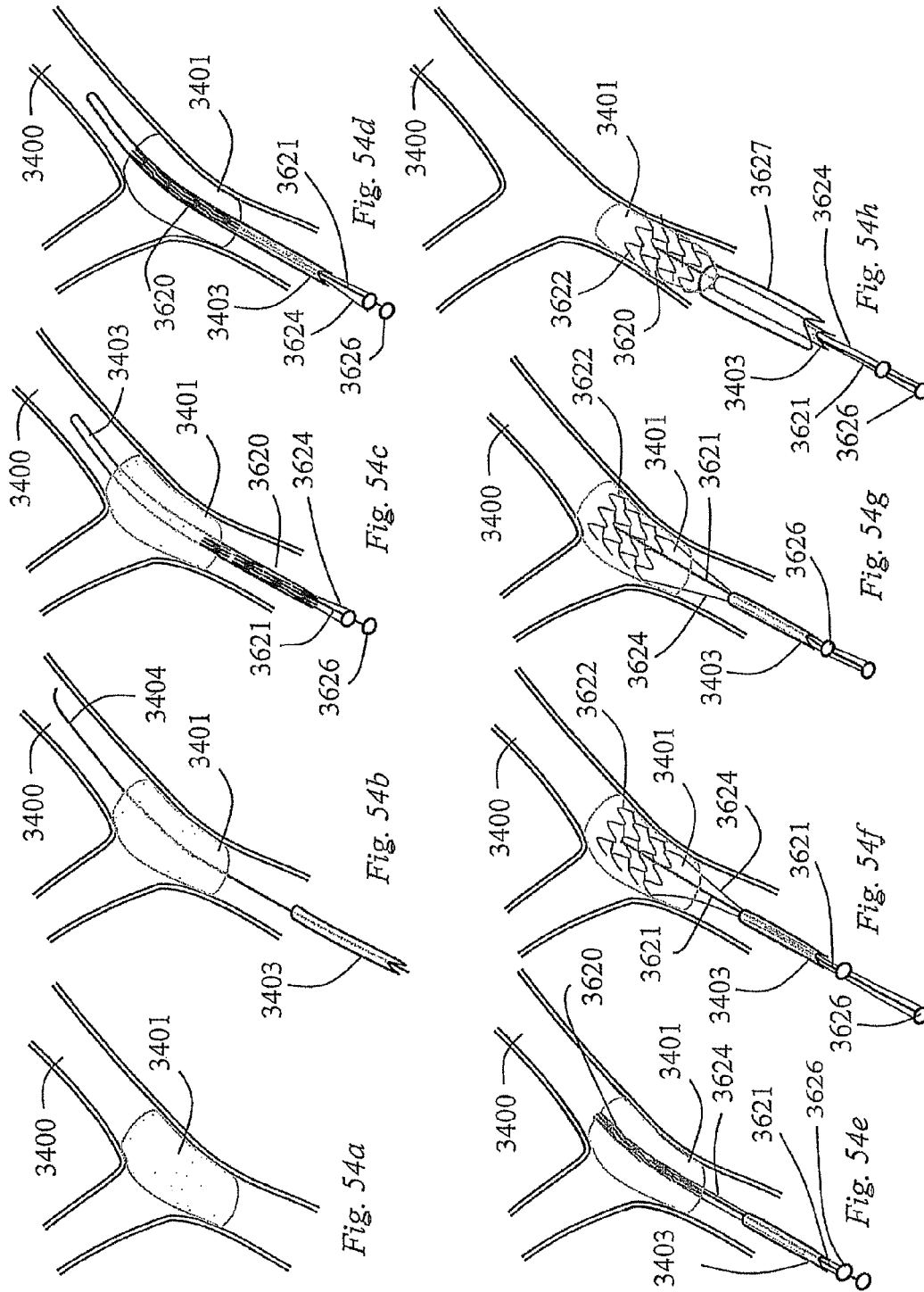


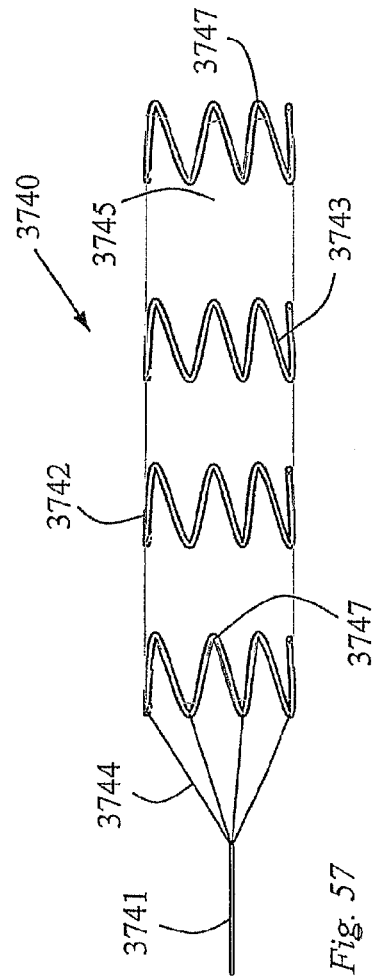
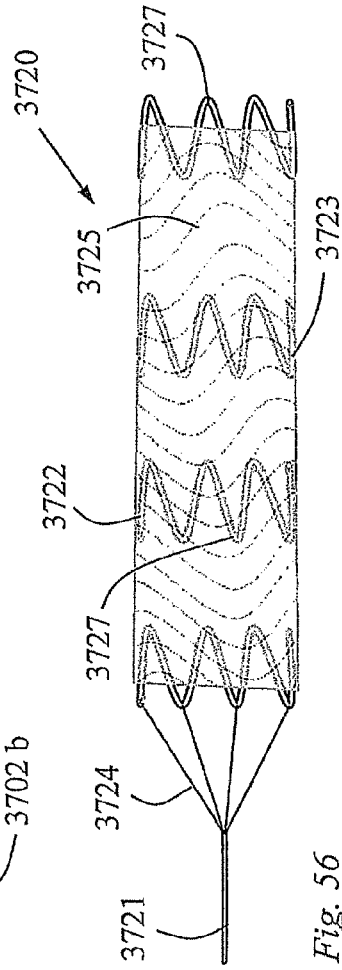
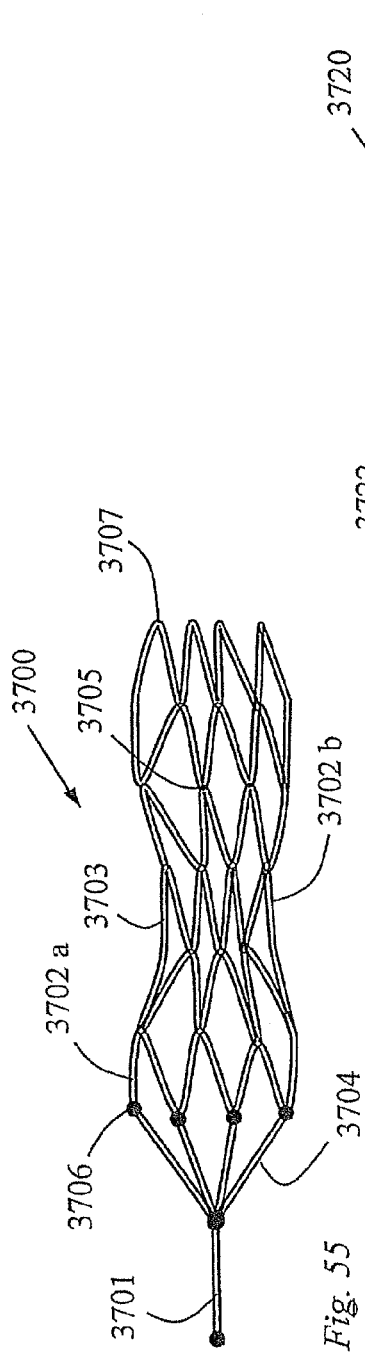












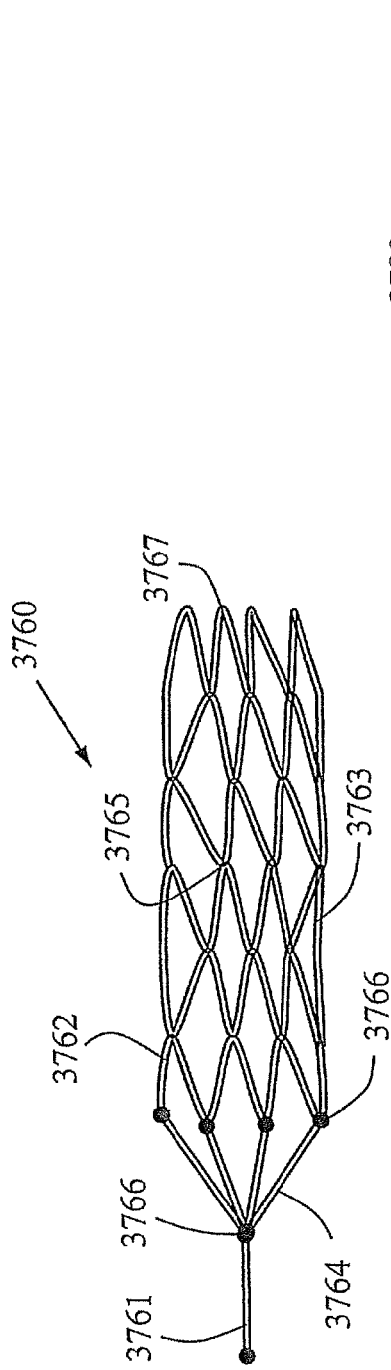


Fig. 58

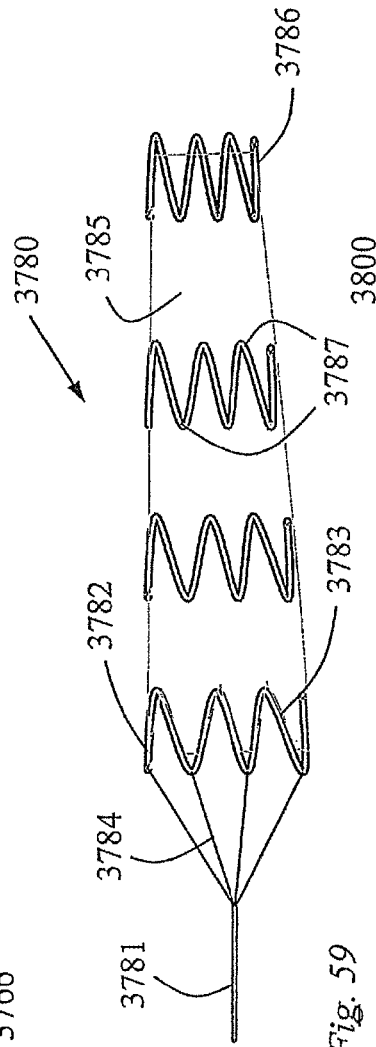


Fig. 59

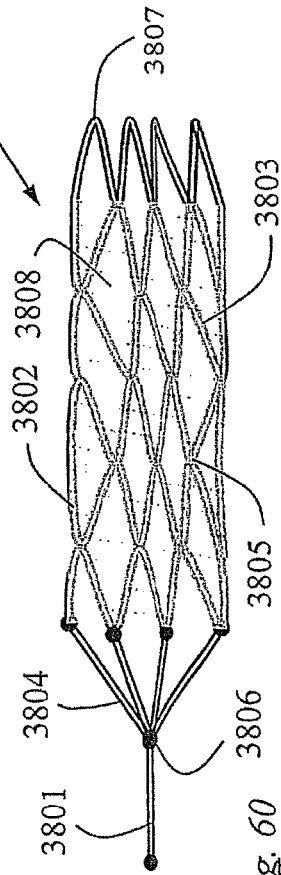
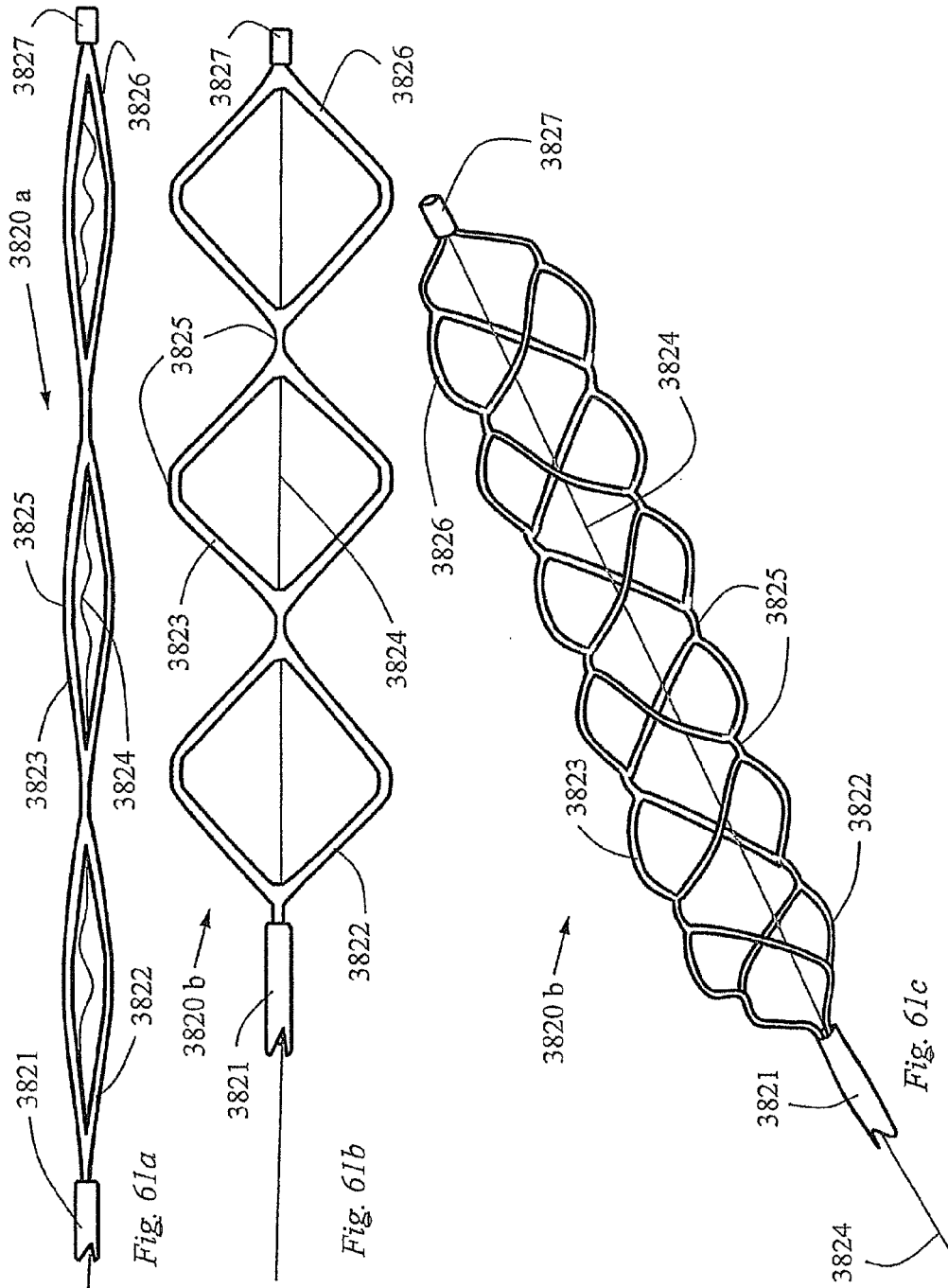
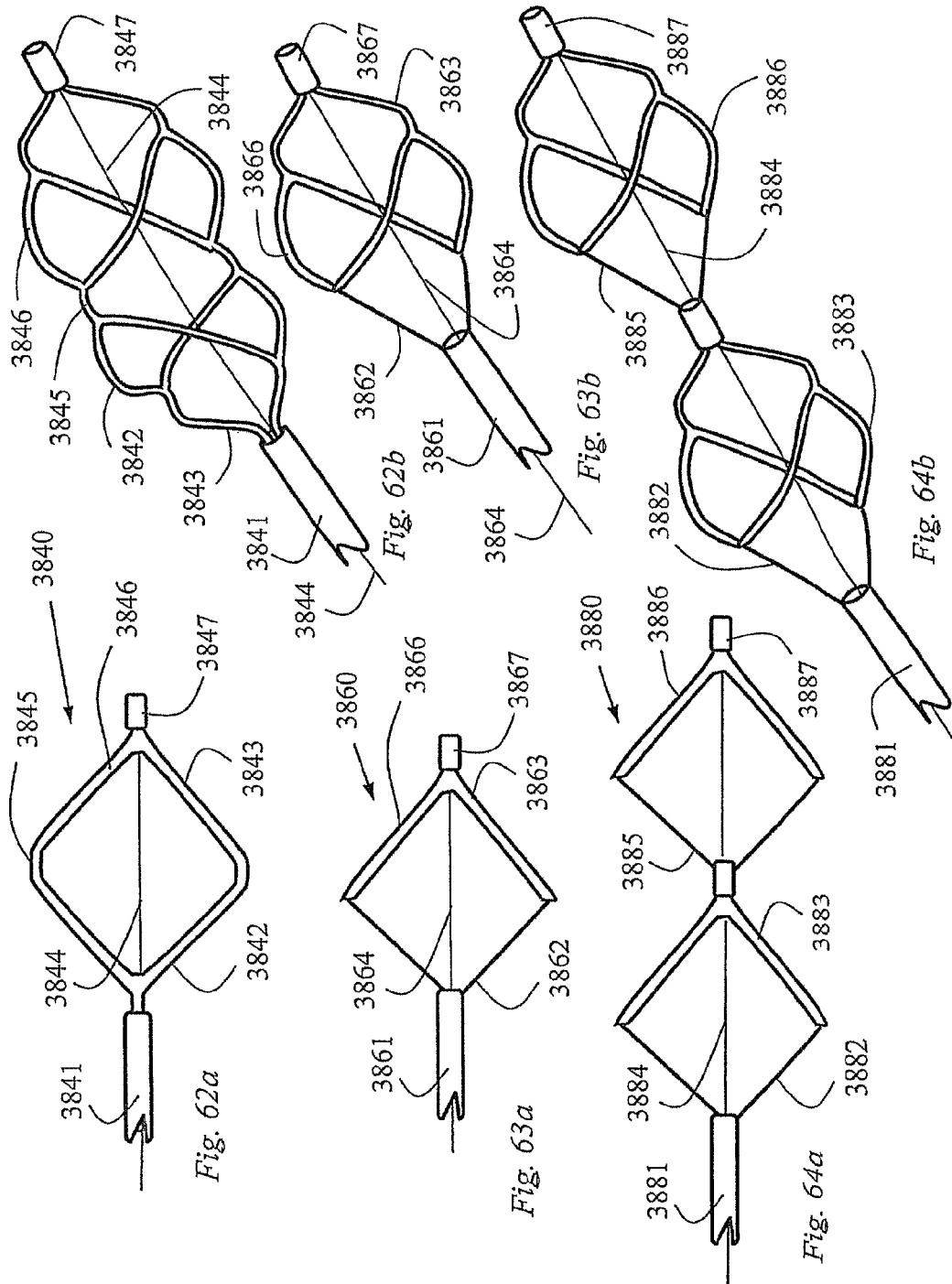
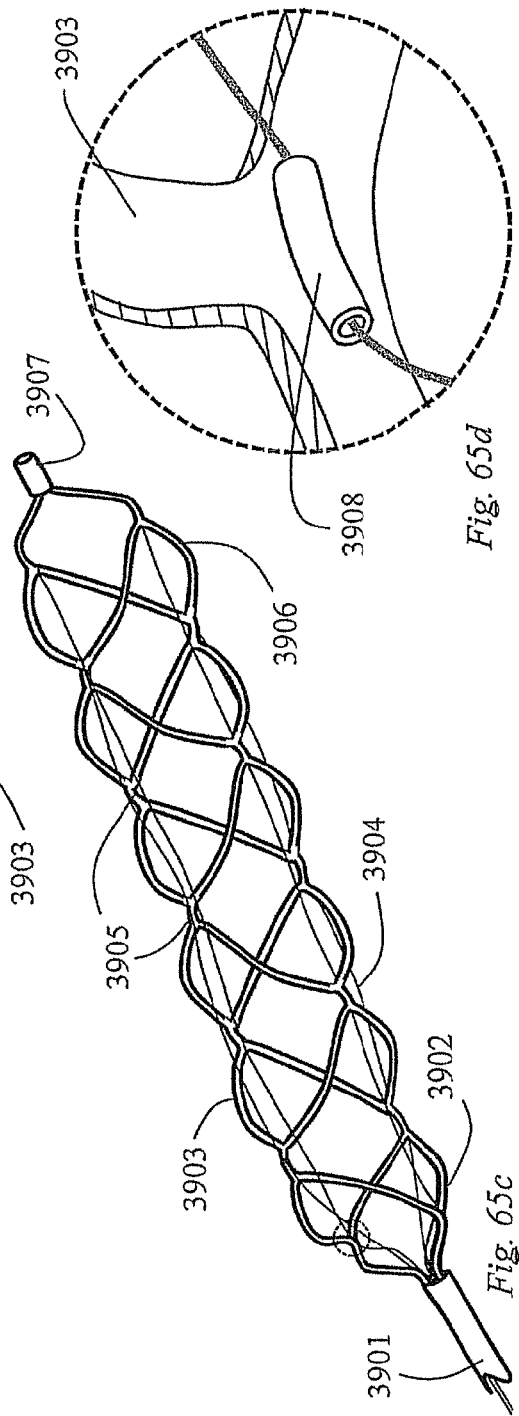
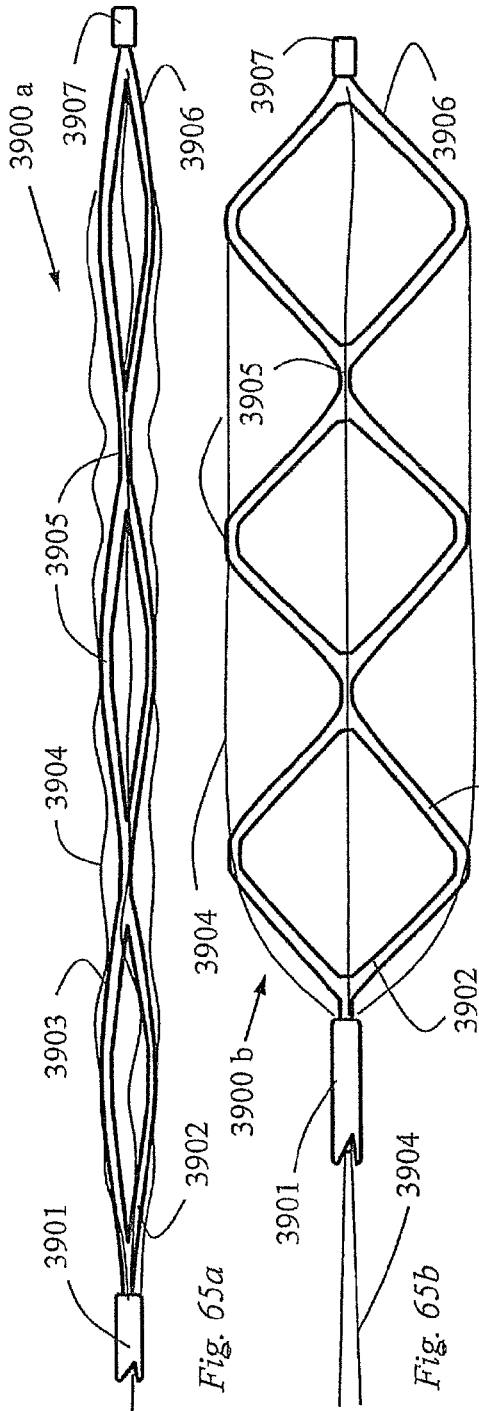


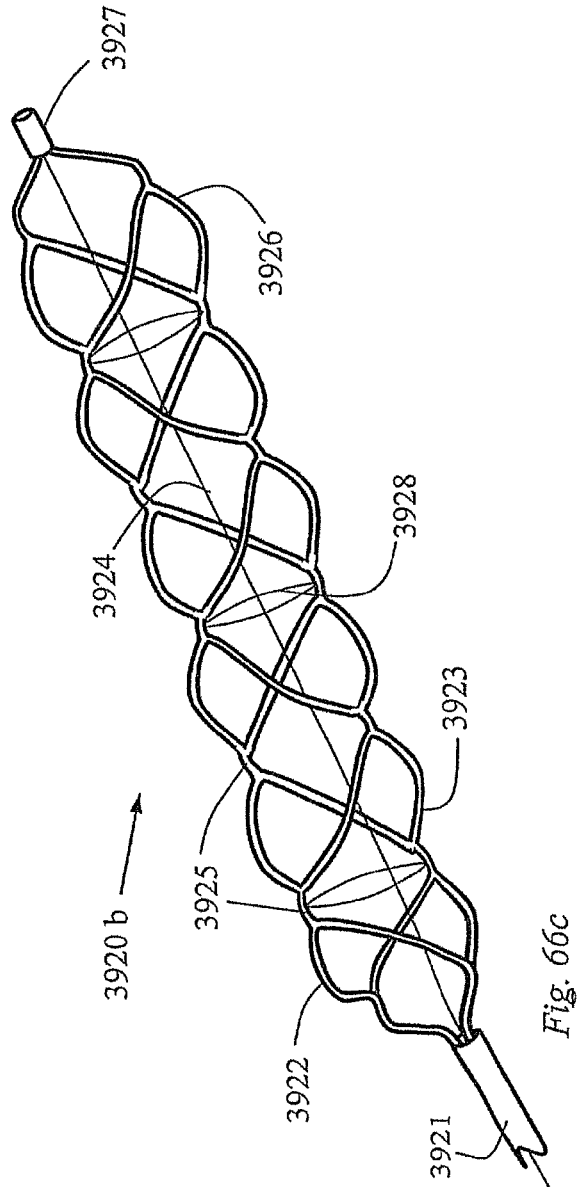
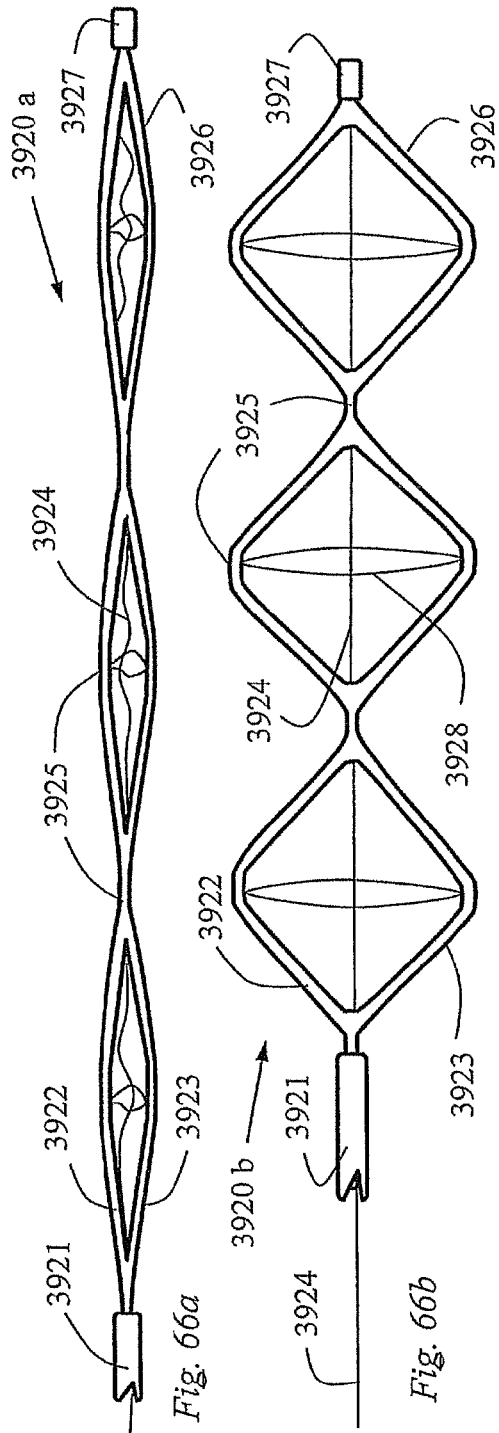
Fig. 60

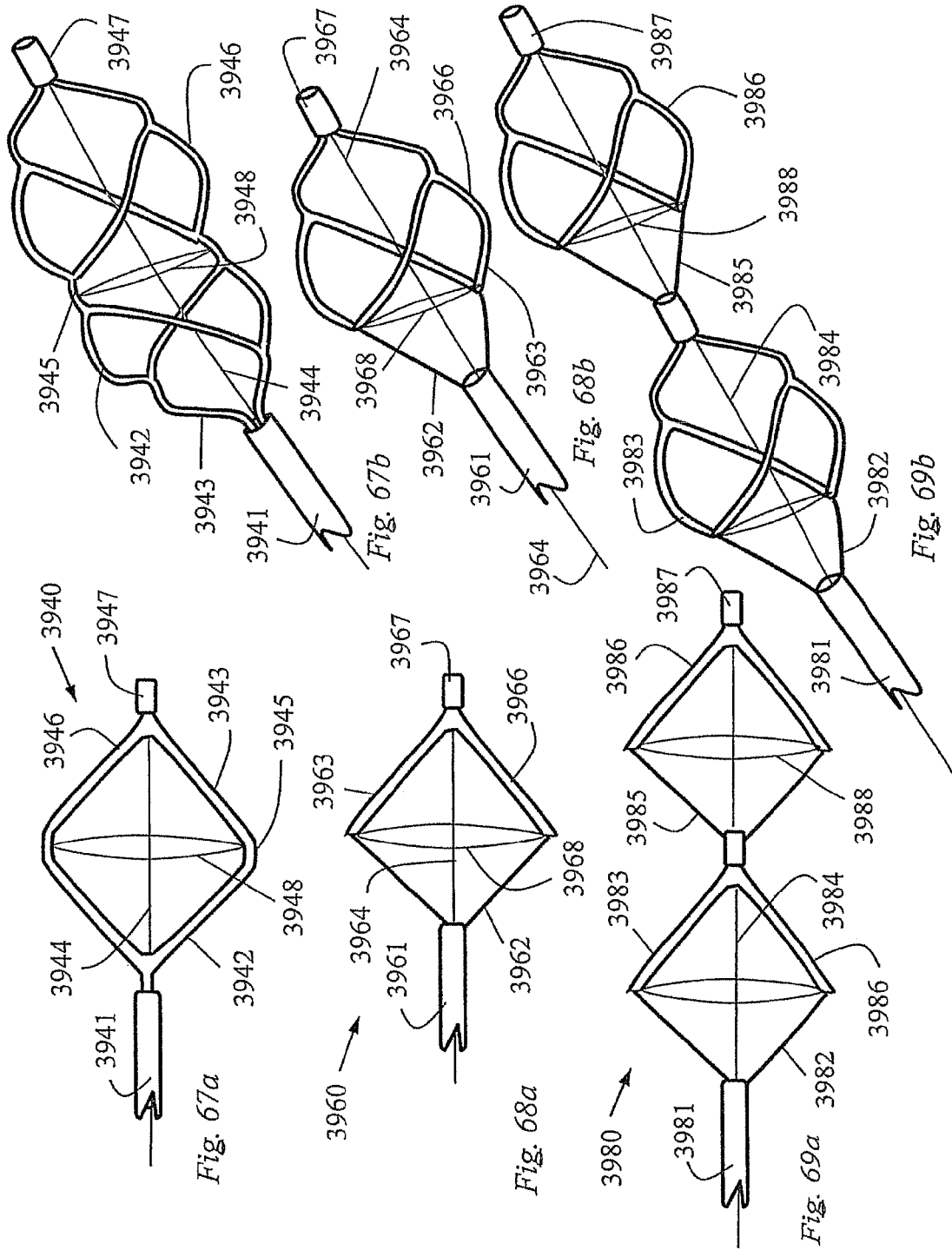












1

**CLOT RETRIEVAL DEVICES****FIELD OF THE INVENTION**

The present invention relates generally to the field of distal mechanical thrombectomy, more particularly, to a self-expandable mechanical clot retrieval device used in the treatment of acute ischemic stroke and pulmonary embolism in a patient. The retrieval device is of extremely small size delivered through an intravascular microcatheter and meticulously designed to remain in a collapsed state while advancing through the microcatheter to remove thrombus or embolus from the blocked arteries.

**DISCUSSION OF THE PRIOR ART**

Acute ischemic stroke remains one of the major causes of death and disability worldwide. It refers to stroke caused by thrombosis or embolism creating an acute blockage in vasculature that stops flow of blood and deprives the surrounding brain tissue of oxygen. In the absence of oxygen, the brain cells of the immediate area begin to die and release a cascade of toxic chemicals that threaten brain tissue in the surrounding area.

Similarly, pulmonary embolism is a common and potentially fatal condition, creating a sudden blockage in a lung artery caused by any naturally occurring embolus traveling through the arteries of the lung and occluding a small artery that stops the flow of blood and deprives the surrounding lung tissue of oxygen. In the absence of oxygen, the lung tissues in the immediate area succumb to lysis as they are unable to process sufficient oxygen into the blood.

Importantly, both acute ischemic stroke and pulmonary embolism can be avoided and treated by removing the acute blockage and restoring blood flow to the affected area. In recent years, significant advances have been made to prevent ischemic stroke and pulmonary embolism through endovascular procedures involving the use of distal mechanical clot retrieval devices on the end of catheters to manually retract clot and fragments of clot.

Generally, the distal mechanical devices are delivered endovascularly and advanced by guidewire and microcatheter until the device is located distal of the clot where it expands. Thus force is applied to the distal surface of the clot to dislodge it from the artery wall where it is caught and retracted proximally by the retrieval device.

Despite continuous advances made in the art of distal mechanical thrombectomy, there is still much room for improvement in effectively removing acute blockage particularly in engaging and retracting thrombus or embolus from extremely small vasculature. The present invention is an efficient and meticulous approach to improve upon the distal mechanical thrombectomy.

**SUMMARY OF THE INVENTION**

Various aspects of the present invention concern a self-expandable mechanical clot retrieval device that effectively and reliably removes thrombus or embolus from blocked vasculature. It is designed variously to dislodge, engage and retract blood clot from extremely small and tortuous vasculature. The retrieval device comprises an elongate member and a plurality of ring elements. The ring elements may comprise a plurality of struts and crowns interconnected by a tether formed at a distal end of the elongate member or may be a separate component attached thereto. In one aspect, at least one tether connects each ring element to the

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elongate member to restrain the ring element in a collapsed configuration during delivery of the retrieval device through an intravascular microcatheter. The tether connecting the ring element to the elongate member disengages when the retrieval device is positioned at the occluded site and the microcatheter is retracted to allow the self-expandable ring elements to reach an expanded configuration. Preferably, the self-expandable ring elements are formed of shape memory material such as Nitinol.

Additional aspects of the present invention concern methods of using the mechanical clot retrieval device described in the previous paragraph. It is used in the treatment of acute ischemic stroke and pulmonary embolism in a patient. The method of removing the blood clot from a blocked artery includes advancing a self-expandable mechanical clot retrieval device having an elongate member and a plurality of self-expandable ring elements arranged at a distal end of the elongate member through the vasculature to a blockage site in the artery. The retrieval device bypasses the clot and is positioned distal to the clot to allow the self-expandable ring elements to reach an expanded configuration in order to engage the clot within expanded ring elements and is proximally retracted from the artery. The method may include retracting the expanded ring elements proximally into a guide catheter or a microcatheter.

**STATEMENT OF THE INVENTION**

In a first embodiment of the invention the clot retrieval device comprises an elongate member and a plurality of clot engaging elements at a distal end of the elongate member, the clot engaging elements being self expandable and having a retracted delivery configuration and an expanded deployed configuration; and a biasing element for biasing the clot engaging elements into a retracted delivery configuration against the elongate member; the biasing element being releasable to allow the clot engaging elements to expand into the deployed configuration.

The second embodiment of the invention comprises a method of retrieving a clot comprising the steps of: (1) providing an elongate member and a plurality of clot engaging elements at a distal end of the elongate member, the clot engaging elements having a retracted configuration and an expanded configuration; (2) providing a biasing element for retaining the clot engaging elements in the retracted configuration; (3) advancing a microcatheter across a clot; (4) advancing the elongate member with the clot engaging elements in a retracted configuration through the microcatheter so that at least some of the clot engaging elements are distal of the clot; (5) releasing the biasing so that the clot engaging elements expand to the expanded configuration; (6) engaging the clot engaging elements with a clot; and (7) using the clot engaging elements, drawing the clot into a retrieval element.

A third embodiment of the invention comprises a luminal prosthesis device comprising: an elongate member and a plurality of luminal prosthetic elements at a distal end of the elongate member; the luminal prosthetic elements being self expandable and having a retracted delivery configuration and an expanded deployed configuration; and a biasing element for biasing the luminal prosthetic elements into a retracted delivery configuration against the elongate member; the biasing element being releasable to allow the luminal prosthetic elements to expand into the deployed configuration.

A fourth embodiment of the invention comprises a clot retrieval device comprising: an elongate member and a

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plurality of clot engaging elements at a distal end of the elongate member, the clot engaging elements being self expandable and having a retracted delivery configuration, a retracted deployed configuration and a fully expanded configurations; and providing a release element for biasing the clot engaging elements in at least one retracted configuration; activation of the release element allowing the clot engaging elements to expand into the fully expanded configuration.

In one variation of this embodiment the diameter of the clot engagement elements in the retracted delivery configuration is smaller than the diameter of the clot engagement elements in the retracted deployed configuration and the diameter of the clot engagement elements in the retracted deployed configuration is smaller than the diameter of the clot engagement elements in the fully expanded configuration.

In another variation of this embodiment a release element is configured to bias the clot engaging elements in a retracted deployed configuration. The release element may be integral with the clot engagement elements. The release element may be integral with elongate member. The release element may be connected to either the clot engagement elements, the elongate member or to both. The release element may comprise; a snap element, a restraining element, a tether, an interlocking element, an overlapping element of the clot engagement element, an abutment element, a connector element, a housing element, a pair of interacting elements, or a limiting element configured to limit at least one degree of expansion movement.

In another variation of this embodiment the clot engagement element comprises a plurality of struts and said release element is configured to limit relative movement between at least a pair of said struts. In another variation of this embodiment the release element is configured to limit relative movement between the clot engagement element and the elongate member. The elongate member may be configured to activate the release element.

In another variation of this embodiment the device comprises an activation element said activation element configured to affect the release of the release element. The activation element may comprise an elongate tube, an elongate member, or a tether.

A fifth embodiment of the invention comprises a clot retrieval device comprising: an elongate member and a first clot engaging element and a second clot engaging element the first clot engaging element distal of the second clot engaging element, the clot engaging elements being self expandable and having a sheathed delivery configuration, a deployed configuration and a fully expanded configurations; and providing at least one release element for biasing the clot engaging elements in the deployed configuration; activation of the at least one release element allowing the clot engaging elements to expand into the fully expanded configuration.

In one variation of this embodiment the sheathed configuration comprises sheathing within the lumen of a microcatheter. In another variation of this embodiment the unsheathing the clot engaging elements allows the clot engaging elements to assume the unsheathed configuration. In another variation of this embodiment the diameter of the clot engaging elements in the deployed configuration is greater than the diameter of the clot engaging elements in the sheathed configuration. In another variation of this embodiment the first clot engagement element assumes the expanded configuration while the second clot engaging element is in the deployed configuration.

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A sixth embodiment of the invention comprises a method for retrieval of a clot comprising the steps of: (1) providing a clot retrieval device the clot retrieval device comprising an elongate member and a plurality of clot engaging elements at a distal end of the elongate member, the clot engaging elements having a retracted configuration, a partially expanded configuration and an expanded configuration; (2) providing a biasing element for limiting the expansion of the clot engaging elements; (3) advancing a microcatheter across a clot; (4) advancing the elongate member with the clot engaging elements in a retracted configuration through the microcatheter so that at least some of the clot engaging elements are distal of the clot; (5) retracting the microcatheter so as to unsheath at least one clot engaging element, (6) activating the biasing element so as to trigger the expansion of at least one of said clot engagement elements to the expanded configuration, (7) retracting the clot retrieval device and the clot into a proximal retrieval element.

In one variation of this embodiment the method comprises the step of retracting the microcatheter also comprises the step of expanding the at least one clot engagement element to the partially expanded configuration. In another variation of this embodiment the step of activating the biasing element comprises the step of applying an activation force to the biasing element.

In another variation of this embodiment the step of activating the biasing element comprises the step of applying a compressive, tensile, twisting or radial force to the biasing element.

In another variation of this embodiment the method comprises the step of providing a plurality of clot engagement elements configured such that in the partially expanded configuration a flow lumen extends through the centre of said clot engagement elements, said lumen being larger than the diameter of the microcatheter and smaller than the diameter of the vessel.

In another variation of this embodiment the method comprises the step of holding the clot retrieval device steadfast in the vessel for a dwell time period the dwell time period comprising at least one minute.

A seventh embodiment of the invention comprises a retrieval device for removing occlusive clot from the vasculature the retrieval device comprising: an elongate member and an expandable body connected to the elongate member, the expandable body comprising a plurality of self-expanding clot engaging elements, each clot engaging element comprising a plurality of struts and a plurality of crowns arranged to form at least one ring, at least one of said plurality of crowns comprising an integral connection to an adjacent ring, a spacing between at least two of said clot engaging elements said spacing comprising a variable spacing in use.

In one variation of this embodiment the at least one integral connection comprises a monolithic connection. The at least one integral connection may comprise a connection to a crown of an adjacent ring of the same clot engaging element. The at least one integral connection may comprise a connection to a crown of a ring of an adjacent engaging element. The at least one integral connection may comprise a connection to the elongate member. In another variation of this embodiment the at least one of said plurality of crowns comprises an unconnected crown. In another variation of this embodiment the a pair of adjacent crowns of said expandable body comprise a pair of unconnected crown, the first of said pair of adjacent crowns comprising a proximally facing crown and the second of said pair of adjacent crowns comprising a distally facing crown. The first crown of said

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pair of adjacent crowns may be located on a first clot engaging element and the second crown of said pair of adjacent crowns may be located on a second clot engaging element.

In another variation of this embodiment the clot engaging elements are arranged in series. In another variation of this embodiment the clot engaging elements are arranged in series.

In another variation of this embodiment the clot engagement elements are spaced apart. The spacing between at least two of said clot engaging elements may vary during delivery. The spacing between at least two of said clot engaging elements may vary during engagement with the clot. The spacing between at least two of said clot engaging elements may vary during clot disengagement with the vessel wall. The spacing between at least two of said clot engaging elements may vary during withdrawal of the clot through the vasculature. The spacing between at least two of said clot engaging elements may vary during removal of the clot and device into the lumen of a retrieval catheter. The spacing between at least two of said clot engaging elements may vary across the diameter of the clot engaging elements.

An eighth embodiment of the invention comprises a retrieval device for removing occlusive clot from the vasculature comprising: an elongate member and an expandable body connected to the elongate member, the expandable body comprising an collapsed delivery configuration and an expanded configuration, the expandable body comprising a plurality of self-expanding clot engaging elements, cut from a tube in a monolithic structure, each clot engaging element comprising a plurality of struts and a plurality of crowns arranged to form a ring, at least one pair of adjacent clot engaging elements being spaced apart by a plurality of connector elements, the pair of adjacent clot engaging elements and the plurality of connectors configured to create a plurality of clot engaging cells, the plurality of connectors comprising a plurality of helical strut.

In one variation of this embodiment the plurality of clot engaging cells are configured to scaffold outwardly so as to create a flow lumen through the clot. The plurality of clot engaging cells may be configured to urge clot ingress through the cell openings so that the clot is interlaced with the plurality of engaging cells.

In another variation of this embodiment the helical struts extend circumferentially through an angle of at least 25 degrees. In another variation of this embodiment the helical struts extend circumferentially through an angle of at least 40 degrees. In another variation of this embodiment the helical struts extend circumferentially through an angle of at least 50 degrees. In another variation of this embodiment the helical struts extend axially a distance of at least 500 micrometers. In another variation of this embodiment the helical struts extend axially a distance of at least 750 micrometers. In another variation of this embodiment the helical struts extend axially a distance of at least 900 micrometers.

In another variation of this embodiment the tube from which the expandable body is cut has a diameter larger than the diameter of the expandable body in the collapsed delivery configuration. The tube from which the expandable body is cut may have a diameter equal to or smaller than the expanded diameter of the expandable body.

A ninth embodiment of the invention comprises a mechanical clot retrieval device for use in a blood artery, comprising an elongate member having a distal end and a proximal end, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery;

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and a plurality of self-expandable ring elements configured at the distal end of the elongate member, wherein each ring element, comprising a plurality of struts, is interconnected by ring connecting tethers and is delivered through an intravascular microcatheter in a collapsed configuration inside the artery, wherein the ring elements comprise a radial force biasing ring elements toward an expanded configuration, wherein the radial force is absorbed by the elongate member in the collapsed configuration, wherein the microcatheter is retracted proximally allowing the ring elements reach the expanded configuration.

In one variation of this embodiment each strut comprises a crown element. The crown element may comprise an engagement member and a fixed tab. The crown element may comprise an engagement member and an engagement hook. The crown element may comprise an engagement member and a connector. The crown element may comprise an engagement member and an engagement tab. The crown element may engage a neighboring crown element in a snap-fit mechanism.

In another variation of this embodiment the snap-fit mechanism restrains the ring elements in the collapsed configuration. The ring elements in the collapsed configuration may be substantially parallel along the longitudinal axis of the elongate member. In another variation of this embodiment the device comprises a proximal fixed collar configured proximally of the ring elements. In another variation of this embodiment the device further comprises a push tube attached to the proximal fixed collar.

In another variation of this embodiment the device further comprises a distal moveable collar configured distally of the ring elements. In another variation of this embodiment the device comprises a balloon. In another variation of this embodiment the balloon is delivered in a deflated state. In another variation of this embodiment the device further comprises a ball element. In another variation of this embodiment the device further comprises a pair of pull tethers having distal and proximal ends. In another variation of this embodiment the distal ends are connected to the most proximal ring element. In another variation of this embodiment the distal ends are attached to the connector. In another variation of this embodiment the distal ends are attached to the engagement tab.

In another variation of this embodiment the distal ends are attached to the distal movable collar. In another variation of this embodiment the proximal ends extend exterior of the artery. The proximal ends may be manually pulled proximally to disengage the snap-fit mechanism. The proximal ends may be attached to the elongate member. In another variation of this embodiment the balloon is inflated to disengage the snap-fit mechanism. In another variation of this embodiment the ball element is manually retracted proximally to disengage the snap-fit mechanism.

A tenth embodiment of the invention comprises a mechanical clot retrieval device for use in an artery, comprising an elongate member having a distal end and a proximal end, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery; and a plurality of self-expandable ring elements configured at the distal end of the elongate member, wherein each ring element, comprising a plurality of struts, is attached to the elongate member by connecting tethers and is delivered through an intravascular microcatheter in a collapsed configuration, wherein the ring elements comprise a radial force biasing the ring elements toward an expanded configuration, wherein the radial force is absorbed by the elongate member

in the collapsed configuration, wherein the microcatheter is retracted proximally allowing the ring elements to reach the expanded configuration.

In one variation of this embodiment each strut comprises a crown element. In another variation of this embodiment the proximally facing crown element is a ring proximal crown and distally facing crown element is a ring distal crown. The ring proximal crown may be attached to the elongate member by connecting tethers. The crown element may be engaged with the elongate member in a snap-fit mechanism. The snap-fit mechanism restrains the ring elements in the collapsed configuration. The elongate member is manually retracted to disengage the snap-fit mechanism. In another variation of this embodiment the elongate member is attached to at least one ring element in the expanded configuration.

A eleventh embodiment of the invention comprises a mechanical clot retrieval device for use in an artery, comprising an elongate member having a distal end and a proximal end, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery; and a plurality of self-expandable ring elements configured at the distal end of the elongate member, wherein each ring element comprising a plurality of struts is interconnected by ring connecting tethers and is delivered through an intravascular microcatheter in a collapsed configuration, wherein the ring elements comprise a radial force biasing the ring elements toward an expanded configuration, wherein the microcatheter is retracted allowing the ring elements to reach the expanded configuration.

In one variation of this embodiment each strut comprises a crown element. The crown element may be attached to the elongate member by a bonding agent. The bonding agent restrains the ring elements in the collapsed configuration. The bonding agent may be dissolved in vivo allowing the ring elements reach the expanded configuration. The radial force may be absorbed by the bonding agent.

In another variation of this embodiment the crown element is attached to the elongate member by a resorbable covering. The re-absorbable covering restrains the ring elements in the collapsed configuration. The re-absorbable covering may be dissolved in vivo allowing the ring elements to reach the expanded configuration. The radial force may be absorbed by the re-absorbable covering. In another variation of this embodiment the device comprises a pair of pull tethers having distal and proximal ends. The distal ends of said tethers are attached to most the proximal ring element. The proximal ends of said tethers extend exterior of the artery.

An twelfth embodiment of the invention comprises a mechanical clot retrieval device for use in vasculature, comprising an elongate member having a distal end, a proximal end and a plurality of radial pins, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery; and a plurality of self-expandable ring elements configured at the distal end of the elongate member, wherein each ring element, comprising a plurality of struts, is advanced through an intravascular microcatheter in a collapsed configuration, wherein the ring elements comprise a radial force biasing the ring elements toward an expanded configuration, wherein the radial force is absorbed by radial pins in the collapsed configuration, wherein the microcatheter is retracted allowing the ring elements to reach the expanded configuration.

In one variation of this embodiment the radial pin has an engagement member. In another variation of this embodiment each strut comprises a crown element. The crown

element may comprise a plurality of eyelets. In another variation of this embodiment the distally facing eyelet engages with the radial pin. The distally facing eyelet may fasten the ring elements to the elongate member.

In another variation of this embodiment the proximally facing eyelet engages with the radial pins in a snap-fit mechanism. In another variation of this embodiment the snap-fit mechanism restrains the ring elements in the collapsed configuration. In another variation of this embodiment the engagement member is dissolved in vivo to disengage the snap-fit mechanism. In another variation of this embodiment the engagement member is dissolved in vivo allowing the ring elements to reach the expanded configuration.

An thirteenth embodiment of the invention comprises a mechanical clot retrieval device for use in vasculature, comprising an elongate member having a distal end, a proximal end, an outer tube having a plurality of slots and a retractable inner core wire, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery; a plurality of self-expandable ring elements configured at the distal end of the elongate member, wherein each ring element, comprising a plurality of struts, is interconnected by ring connecting tethers and is delivered through an intravascular microcatheter in a collapsed configuration, wherein the ring elements comprise a radial force biasing the ring elements toward an expanded configuration, wherein the radial force is absorbed by the inner core wire in the collapsed configuration, wherein the microcatheter is retracted proximally allowing the ring elements to reach the expanded configuration.

In one variation of this embodiment each strut comprises a crown element having an eyelet. In another variation of this embodiment a tether is advanced out of the slot to loop through the eyelet and folds back into the slot to loop around the retractable inner core wire. The tether may engage the ring elements with the elongate member in a tether-loop mechanism. In another variation of this embodiment the tether-loop mechanism restrains the ring elements in the collapsed configuration.

In another variation of this embodiment the retractable inner core wire is manually retracted proximally to disengage the tether-loop mechanism. The retractable inner core wire may be advanced out of each slot to loop through each eyelet and folds back into the slot to loop inside the outer tube. The retractable inner core wire may engage the ring elements with the elongate member in a tether-loop mechanism.

In another variation of this embodiment the tether-loop mechanism restrains the ring elements in the collapsed configuration. In another variation of this embodiment the retractable inner core wire is manually retracted proximally to disengage the tether-loop mechanism.

An fourteenth embodiment of the invention comprises a mechanical clot retrieval device for use in vasculature, comprising an elongate member having a distal end, a proximal end and a tube lumen having a plurality of slots, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery; and a plurality of self-expandable ring elements configured at the distal end of the elongate member, wherein each ring element, comprising a plurality of struts, is interconnected by ring connecting tethers and is delivered through an intravascular microcatheter in a collapsed configuration, wherein the ring elements comprise a radial force biasing the ring elements toward an expanded configuration, wherein the microcath-

eter is retracted proximally allowing the ring elements to reach the expanded configuration.

In one variation of this embodiment each strut comprises a crown element having an eyelet. In another variation of this embodiment the device further comprises a plurality of tethers, having distal ends that extend interior of the tube lumen and proximal ends that extend exterior of the artery. Each tether may be advanced through a slot to loop around the eyelet and folded back into the slot attached to the distal end of the elongate member. Each tether may engage the ring elements with the elongate member in a tether-loop mechanism. The tether-loop mechanism may restrain the ring elements in the collapsed configuration. Each tether may be broken to disengage the snap-fit mechanism allowing ring elements to reach the expanded configuration.

An fifteenth embodiment of the invention comprises a mechanical clot retrieval device for use in a blood artery, comprising an elongate member having a distal end and a proximal end, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery; a proximal collar attached to an abutment tube; and a plurality of self-expandable ring elements configured at the distal end of the elongate member, wherein each ring element, comprising a plurality of struts, is attached to the elongate member by connecting tethers and is advanced through an intravascular microcatheter in a collapsed configuration, wherein the ring elements comprise a radial force biasing the ring elements toward an expanded configuration, wherein the microcatheter is retracted allowing the ring elements to reach the expanded configuration.

In one variation of this embodiment each strut comprises a crown element. In another variation of this embodiment the device further comprises a plurality of tethers. Each tether may be looped around the ring element and is attached to the elongate member.

Each tether may engage the ring elements with the elongate member in a tether-loop mechanism. The radial force may be absorbed by the tether-loop mechanism. The tether-loop mechanism may restrain the ring elements in the collapsed configuration. In another variation of this embodiment the elongate member may be manually retracted proximally to disengage the tether-loop mechanism.

A sixteenth embodiment of the invention comprises a mechanical clot retrieval device for use in vasculature, comprising an elongate member having a distal end and a proximal end, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery; a plurality of collars configured at the distal end of the elongate member; and a plurality of self-expandable ring elements configured at the distal end of the elongate member, wherein each ring element is configured between two collars, wherein each ring element, comprising a plurality of struts, is interconnected by ring connecting tethers and is delivered through an intravascular microcatheter in a collapsed configuration, wherein the ring elements comprise a radial force biasing the ring elements toward an expanded configuration, wherein the radial force is absorbed by the collars in the collapsed configuration, wherein the microcatheter is retracted allowing the ring elements reach the expanded configuration.

In one variation of this embodiment the collar is bevel shaped or the collar is recess shaped or the collar is a shaped engagement collar or the collar has a plurality of holes or the collar has a plurality of dove tail grooves.

In one variation of this embodiment each strut comprises a crown element. In one variation of this embodiment the crown element has a tab extending axially and radially

inward. The crown element may have a pin extending axially and radially inward. The crown element may have a shaped tab extending axially and radially inward and the tab may be bevel shaped. The tab may be square shaped. The tab may engage with the collar in a collar mechanism.

In another variation of this embodiment the collar mechanism engages the ring elements with the elongate member. The collar mechanism may restrain the ring elements in the collapsed configuration. In another variation of this embodiment the elongate member is manually retracted proximally to disengage the collar mechanism.

In another variation of this embodiment the pin engages with the hole in a collar mechanism. In another variation of this embodiment the collar mechanism engages the ring elements with the elongate member. In another variation of this embodiment the collar mechanism restrains the ring elements in the collapsed configuration. In another variation of this embodiment the elongate member is manually retracted proximally to disengage the collar mechanism.

In another variation of this embodiment the shaped tab engages with the dove tail groove in a collar mechanism. In another variation of this embodiment the collar mechanism engages the ring elements with the elongate member. In another variation of this embodiment the collar mechanism restrains the ring elements in the collapsed configuration. In another variation of this embodiment the elongate member is manually retracted proximally to disengage the collar mechanism.

A seventeenth embodiment of the invention comprises a mechanical clot retrieval device for use in vasculature, comprising an elongate member having a distal end and a proximal end, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery; a proximal collar; and a self-expandable ring element configured at the distal end of the elongate member, wherein the ring element, comprising a plurality of struts, is delivered through an intravascular microcatheter in a collapsed configuration, wherein the ring element comprises a radial force biasing the ring element towards an expanded configuration, wherein the radial force is absorbed by the proximal collar in the collapsed configuration, wherein the microcatheter is retracted allowing the ring element to reach the expanded configuration.

In one variation of this embodiment each strut comprises a crown element having a tab extending axially and radially inward. In another variation of this embodiment the tab engages with the proximal collar in a collar mechanism. In another variation of this embodiment the collar mechanism engages the ring element with the elongate member. In another variation of this embodiment the collar mechanism restrains the ring element in the collapsed configuration. In another variation of this embodiment the elongate member is manually retracted proximally to disengage the collar mechanism.

A eighteenth embodiment of the invention comprises a mechanical clot retrieval device for use in vasculature, comprising an elongate member having a distal end, a proximal end and inner lumen having a plurality of openings, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery; and a plurality of self-expandable ring elements configured at the distal end of the elongate member, wherein each ring element, comprising a plurality of struts, is interconnected by ring connecting tethers and is delivered through an intravascular catheter in a collapsed configuration, wherein the ring elements comprise a radial force biasing the ring

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elements toward an expanded configuration, wherein the microcatheter is retracted allowing the ring elements reach the expanded configuration.

In one variation of this embodiment each strut comprises a crown element and an engagement tab. In one variation of this embodiment the device further comprises a plurality of tethers having proximal ends extend exterior of the inner lumen. In one variation of this embodiment each tether is advanced out of each opening and is wrapped around the engagement tab in an eyelet mechanism. In one variation of this embodiment the eyelet mechanism engages the ring elements with the elongate member. In one variation of this embodiment the eyelet mechanism restrains the ring elements in the collapsed configuration.

In one variation of this embodiment the radial force is absorbed by the eyelet mechanism. In one variation of this embodiment the tethers are manually pulled proximally to disengage the eyelet mechanism.

A nineteenth embodiment of the invention comprises a mechanical clot retrieval device for use in a blood artery, comprising an elongate member having a distal end, a proximal end and a plurality of raised tabs, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery; and a plurality of self-expandable ring elements configured at the distal end of the elongate member, wherein each ring element, comprising a plurality of struts, is interconnected by ring connecting tethers and is delivered through an intravascular microcatheter in a collapsed configuration, wherein the ring elements comprise a radial force biasing the ring elements towards an expanded configuration, wherein the radial force is absorbed by the raised tabs in the collapsed configuration, wherein the microcatheter is retracted allowing the ring elements to reach the expanded configuration.

The variations described in association with each of the embodiments 1 through to 19 can be applied to the 20<sup>th</sup> through to the 36<sup>th</sup> embodiments (below) and are hereby incorporate as variations to each of the 20<sup>th</sup> through to the 36<sup>th</sup> embodiments.

A twentieth embodiment of the invention comprises a mechanical clot retrieval device for use in vasculature, comprising an elongate member having a distal end, a proximal end, a plurality of engagement diameters and a plurality of disengagement diameters, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery; a proximal abutment tube; and a plurality of self-expandable ring elements configured at the distal end of the elongate member, wherein each ring element, comprising a plurality of struts, is interconnected by ring connecting tethers and is delivered through an intravascular microcatheter in a collapsed configuration, wherein the ring elements comprise a radial force biasing the ring elements toward an expanded configuration, wherein the radial force is absorbed by engagement diameters in the collapsed configuration, wherein the microcatheter is retracted allowing the ring elements to reach the expanded configuration. Each strut may comprise a crown element having a C-shaped engagement tab extending radially inward. The C-shaped engagement tab engages with the engagement diameter to restrain the ring elements along the elongate member. The C-shaped engagement tab engages with the engagement diameter to restrain the ring element in the collapsed configuration. In one variation of this embodiment proximal axial movement of the elongate member disengages the ring element at the disengagement diameter.

A twenty first embodiment of the invention comprises a mechanical clot retrieval device for use in vasculature,

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comprising an elongate member having a distal end, a proximal end and an inner wire, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery; a proximal abutment tube; and a plurality of self-expandable ring elements configured at the distal end of the elongate member, wherein each ring element, comprising a plurality of struts, is interconnected by ring connecting tethers and is delivered through an intravascular microcatheter in a collapsed configuration, wherein the ring elements comprise a radial force biasing the ring elements toward an expanded configuration, wherein the radial force is absorbed by the elongate member in the collapsed configuration, wherein the microcatheter is retracted allowing the ring elements to reach the expanded configuration.

A twenty second embodiment of the invention comprises a mechanical clot retrieval device for use in vasculature, comprising: an elongate member having a distal end, a proximal end and an inner lumen with a plurality of slots, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery; a proximal collar; and a plurality of self-expandable ring elements configured at the distal end of the elongate member, wherein each ring element, comprising a plurality of struts, is interconnected by ring connecting tethers and is delivered through an intravascular microcatheter in a collapsed configuration, wherein the ring elements comprise a radial force biasing the ring elements toward an expanded configuration, wherein the radial force is absorbed by slots in the collapsed configuration, wherein the microcatheter is retracted allowing the ring elements to reach the expanded configuration.

A twenty third embodiment of the invention comprises a mechanical clot retrieval device for use in vasculature, comprising: an elongate member having a distal end, a proximal end and a plurality of monofilaments, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery; a proximal collar; and a plurality of self-expandable ring elements configured at the distal end of the elongate member, wherein each ring element, comprising a plurality of struts, is interconnected by ring connecting tethers and is delivered through an intravascular microcatheter in a collapsed configuration, wherein the ring elements comprise a radial force biasing the ring elements in an expanded configuration, wherein the radial force is absorbed by monofilaments in the collapsed configuration, wherein the microcatheter is retracted allowing the ring elements to reach the expanded configuration.

A twenty fourth embodiment of the invention comprises a mechanical clot retrieval device for use in vasculature, comprising: an elongate member having a distal end, a proximal end and a plurality of inactivated cuffs configured at the distal end of the elongate member, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery; a tube; and a plurality of self-expandable ring elements configured over the inactivated cuffs, wherein each ring element, comprising a plurality of struts, is interconnected by ring connecting tethers and is delivered through an intravascular microcatheter in a collapsed configuration, wherein the ring elements comprise a radial force biasing the ring elements towards an expanded configuration, wherein the microcatheter is retracted allowing the ring elements to reach the expanded configuration.

A twenty fifth embodiment of the invention comprises a mechanical clot retrieval device for use in vasculature, comprising an elongate member having a distal end and a proximal end, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery; a



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proximal collar; a bumper tube; and a plurality of self-expandable ring elements configured at the distal end of the elongate member, wherein each ring element, comprising a plurality of struts, is interconnected by ring connecting tethers and is delivered through an intravascular microcatheter in a collapsed configuration; wherein the ring elements comprise a radial force biasing the ring elements toward an expanded configuration, wherein the microcatheter is retracted allowing the ring elements to reach the expanded configuration.

A twenty sixth embodiment of the invention comprises a mechanical clot retrieval device for use in vasculature, comprising: an elongate member having a distal end, a proximal end and a plurality of restraining loops configured at the distal end of the elongate member, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery; and a plurality of self-expandable ring elements configured at the distal end of the elongate member, wherein each ring element, comprising a plurality of struts, is connected to the restraining loop by connecting tethers, wherein the ring elements have a radial force biasing the ring elements toward an expanded configuration, wherein the radial force is absorbed by the restraining loops in a collapsed configuration.

A twenty seventh embodiment of the invention comprises a mechanical clot retrieval device for use in vasculature, comprising: an elongate member having a distal end and a proximal end, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery; a bumper tube; a proximal collar; and a plurality of self-expandable ring elements configured at the distal end of the elongate member, wherein each ring element comprising a plurality of struts is interconnected by ring connecting tethers, wherein the ring elements comprise a radial force biasing the ring elements toward an expanded configuration, wherein the radial force is absorbed by the elongate member in a collapsed configuration.

A twenty eighth embodiment of the invention comprises a mechanical clot retrieval device for use in a tortuous vessel, comprising an elongate member having a distal end and a proximal end, wherein the distal end extends interior of the vessel and the proximal end extends exterior of the vessel; and a plurality of self-expandable ring elements configured at the distal end of the elongate member, wherein each ring element, comprising a plurality of struts, is interconnected by ring connecting tethers and is delivered through an intravascular microcatheter in a collapsed configuration, wherein the ring elements have a radial force biasing the ring elements toward an expanded configuration, wherein the radial force is absorbed by the microcatheter in the collapsed configuration, wherein the microcatheter is retracted allowing the ring elements to reach the expanded configuration.

A twenty ninth embodiment of the invention comprises a mechanical clot retrieval device for use in a tortuous vessel, comprising an elongate member having a distal end and a proximal end, wherein the distal end extends interior of the vessel and the proximal end extends exterior of the vessel; a plurality of self-expandable ring elements having a first diameter and a second diameter, wherein each ring element, comprising a plurality of struts, is interconnected by ring connecting tethers and is delivered through an intravascular microcatheter in a collapsed configuration; and a control strut having distal end attached to most proximal ring element and proximal end attached to the elongate member by adhesive bonds, wherein the ring elements have a radial force biasing the ring elements toward an expanded con-

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figuration, wherein the radial force is absorbed by the microcatheter in the collapsed configuration, wherein the microcatheter is retracted proximally allowing the ring elements to reach the expanded configuration.

A thirtieth embodiment of the invention comprises a mechanical clot retrieval device for use in a tortuous vessel, comprising an elongate member having a distal end and a proximal end, wherein the distal end extends interior of the vessel and the proximal end extends exterior of the vessel; and a plurality of self-expandable ring elements, wherein each ring element, comprising a plurality of struts, is interconnected by ring connecting tethers and is delivered through an intravascular microcatheter in a collapsed configuration; and wherein the ring elements have a radial force biasing the ring elements towards an expanded configuration, wherein the radial force is absorbed by the microcatheter in the collapsed configuration, wherein the microcatheter is retracted proximally allowing the ring elements reach the expanded configuration.

A thirty first embodiment of the invention comprises a mechanical clot retrieval device for use in a tortuous vessel, comprising: an elongate member having a distal end and a proximal end, wherein the distal end extends interior of the vessel and the proximal end extends exterior of the vessel; a plurality of self-expandable ring elements configured at the distal end of the elongate member, wherein each ring element comprises a plurality of struts and is delivered through an intravascular microcatheter in a collapsed configuration; and a plurality of ring connecting tethers having distal and proximal ends, wherein the distal ends are connected to the ring element and the proximal ends are attached to the elongate member, wherein the ring elements have a radial force biasing the ring elements towards an expanded configuration, wherein the radial force is absorbed by the microcatheter in the collapsed configuration, wherein the microcatheter is retracted allowing the ring elements to reach the expanded configuration.

A thirty second embodiment of the invention comprises a mechanical clot retrieval device for use in vasculature, comprising an activation tether having a distal end and a proximal end, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery; a distal collar, wherein the distal end of the activation tether is attached to the distal collar; and a plurality of self-expandable ring elements configured at the distal end of the activation tether, wherein each ring element, comprising a plurality of struts, is interconnected by bridges and is delivered through a microcatheter in a collapsed configuration, wherein the ring elements have a radial force biasing the ring elements towards an expanded configuration, wherein the radial force is absorbed by the microcatheter in the collapsed configuration, wherein the microcatheter is retracted allowing the ring elements reach the expanded configuration.

A thirty third embodiment of the invention comprises a mechanical clot retrieval device for use in vasculature, comprising an activation tether having a distal end and a proximal end, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery; a distal collar, wherein the distal end of the activation tether is attached to the distal collar; and a self-expandable ring element configured at the distal end of the activation tether, wherein the ring element comprises a plurality of struts and is delivered through a microcatheter in a collapsed configuration, wherein the ring element has a radial force biasing the ring element toward the expanded configuration, wherein the radial force is absorbed by the microcatheter in

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the collapsed configuration, wherein the microcatheter is retracted allowing the ring element to reach the expanded configuration.

A thirty fourth embodiment of the invention comprises a mechanical clot retrieval device for use in vasculature, comprising an activation tether having a distal end and a proximal end, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery; a distal collar, wherein the distal end of the activation tether is attached the distal collar; a self-expandable ring element configured at the distal end of the activation tether, wherein the ring element comprises a plurality of struts and is delivered through a microcatheter in a collapsed configuration; and a pair of removal tethers having distal ends attached to the ring element and proximal ends that extend exterior of the artery, wherein the ring element has a radial force biasing the ring element towards an expanded configuration, wherein the radial force is absorbed by the microcatheter in the collapsed configuration, wherein the microcatheter is retracted allowing the ring element to reach the expanded configuration.

A thirty fifth embodiment of the invention comprises a mechanical clot retrieval device for use in vasculature, comprising an activation tether having a distal end and a proximal end, wherein the distal end extends interior of the artery and the proximal end extends exterior of the artery; a couple of collars; a couple of ring elements configured at the distal end of the activation tether, wherein each ring element comprising a plurality of struts and is delivered through a microcatheter in a collapsed configuration; and a pair of removal tethers having distal ends attached to the ring element and proximal ends attached to the collar, wherein the ring elements have a radial force biasing the ring elements toward an expanded configuration, wherein the radial force is absorbed by the microcatheter in the collapsed configuration, wherein the microcatheter is retracted allowing the ring elements to reach the expanded configuration.

A thirty sixth embodiment of the invention comprises a mechanical clot retrieval device for use in vasculature, comprising a pair of activation tethers having distal ends extending interior of the artery and proximal ends extending exterior of the artery; a distal collar, wherein distal ends of the activation tether are attached to the distal collar; and a plurality of self-expandable ring elements configured at distal ends of the activation tethers, wherein the each ring element, comprising a plurality of struts, is interconnected by bridges and is delivered through an intravascular microcatheter in a collapsed configuration, wherein the ring elements have a radial force biasing the ring elements towards an expanded configuration, wherein the radial force is absorbed by the microcatheter in the collapsed configuration, wherein the microcatheter is retracted allowing the ring elements to reach the expanded configuration. The mechanical clot retrieval device in any of the preceding embodiments may comprise a ring element made of shape memory material. The mechanical clot retrieval device in any of the preceding embodiments may comprise a ring element is made of Nitinol. The mechanical clot retrieval device in any of the preceding embodiments may comprise a retrieval device that is made of shape memory material. The mechanical clot retrieval device in any of the preceding embodiments may comprise a retrieval device that is partly made of shape memory material.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be more clearly understood from the following description of some embodiments thereof, given by way of example with reference to the accompanying drawings, in which:

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FIG. 1a is a diagram illustrating a typical occlusive clot in a cerebral artery;

FIG. 1b is an enlarged view of a detail of FIG. 1a;

FIGS. 2a-2h are diagrams illustrating the insertion of a guidewire and the deployment of a clot retrieval device of the invention;

FIGS. 3a-3e illustrate a clot retrieval device according to one embodiment of the invention;

FIGS. 4a-4d illustrate steps involved in using the device of FIGS. 3a-3d;

FIGS. 5a-5e illustrate another clot retrieval device of the invention;

FIGS. 6a-6f illustrate a further clot retrieval device of the invention;

FIGS. 7a-7e illustrate another clot retrieval device of the invention;

FIGS. 8a-8d illustrate a further clot retrieval device of the invention;

FIGS. 9a-9d illustrate another clot retrieval device of the invention;

FIGS. 10a-10d illustrate a further clot retrieval device of the invention;

FIGS. 11a-11h illustrate another clot retrieval device of the invention;

FIGS. 12a-12c illustrate a further clot retrieval device of the invention;

FIGS. 13a-13f illustrate another clot retrieval device of the invention;

FIGS. 14a-14c illustrate a further clot retrieval device of the invention;

FIGS. 15a-15c illustrate a method for using a clot retrieval device of the invention;

FIGS. 16a-16d illustrate another method for using a clot retrieval device of the invention;

FIGS. 17a-17d illustrate a further clot retrieval device of the invention;

FIGS. 18a-18d illustrate another clot retrieval device of the invention;

FIGS. 19a-18d illustrate a further clot retrieval device of the invention;

FIGS. 20a-20b illustrate another clot retrieval device of the invention;

FIGS. 21a-21f illustrate a further clot retrieval device of the invention;

FIGS. 22a-22d illustrate a method for using a clot retrieval device of the invention;

FIGS. 23a-23c illustrate a mechanism used in a clot retrieval device of the invention;

FIGS. 24a-24c illustrate a further clot retrieval device of the invention;

FIGS. 25a-25k illustrate another clot retrieval device of the invention;

FIGS. 26a-26d illustrate a further clot retrieval device of the invention;

FIGS. 27a-27b illustrate another clot retrieval device of the invention;

FIGS. 28a-28b illustrate a further clot retrieval device of the invention;

FIGS. 29a-29h illustrate a method for using a clot retrieval device of the invention;

FIGS. 30a-30e illustrate another clot retrieval device of the invention;

FIGS. 31a-31e illustrate a further clot retrieval device of the invention;

FIGS. 32a-32d illustrate another clot retrieval device of the invention;

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FIGS. 33a-33g illustrate a further clot retrieval device of the invention;

FIGS. 34a-34j illustrate another clot retrieval device of the invention;

FIGS. 35a-35b illustrate a further clot retrieval device of the invention;

FIGS. 36a-36d illustrate another clot retrieval device of the invention;

FIGS. 37a-37i illustrate a further clot retrieval device of the invention;

FIGS. 38a-38d illustrate another clot retrieval device of the invention;

FIGS. 39a-39d illustrate a further clot retrieval device of the invention;

FIGS. 40a-40e illustrate a method for using a clot retrieval device of the invention;

FIGS. 41a-41d illustrate another method for using a clot retrieval device of the invention;

FIGS. 42a-42g illustrate a further clot retrieval device of the invention;

FIGS. 43a-43h illustrate another clot retrieval device of the invention;

FIGS. 44a-44b illustrate a further clot retrieval device of the invention;

FIG. 45 illustrates another clot retrieval device of the invention;

FIG. 46 illustrates a further clot retrieval device of the invention;

FIG. 47 illustrates another clot retrieval device of the invention;

FIGS. 48a-48f illustrate a further clot retrieval device of the invention;

FIGS. 49a-49f illustrate another clot retrieval device of the invention;

FIGS. 50a-50g illustrate a further clot retrieval device of the invention;

FIGS. 51a-51f illustrate another clot retrieval device of the invention;

FIGS. 52a-52d illustrate a further clot retrieval device of the invention;

FIGS. 53a-53f illustrate a method for using a clot retrieval device of the invention;

FIGS. 54a-54h illustrate another method for using a clot retrieval device of the invention;

FIG. 55 illustrates another clot retrieval device of the invention;

FIG. 56 illustrates a further clot retrieval device of the invention;

FIG. 57 illustrates another clot retrieval device of the invention;

FIG. 58 illustrates a further clot retrieval device of the invention;

FIG. 59 illustrates a further clot retrieval device of the invention;

FIG. 60 illustrates another clot retrieval device of the invention;

FIGS. 61a-61c illustrate a further clot retrieval device of the invention;

FIGS. 62a-62b illustrate another clot retrieval device of the invention;

FIGS. 63a-63b illustrate a further clot retrieval device of the invention;

FIGS. 64a-64b illustrate another clot retrieval device of the invention;

FIGS. 65a-65d illustrate a further clot retrieval device of the invention;

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FIGS. 66a-66c illustrate another clot retrieval device of the invention;

FIGS. 67a-67b illustrate a further clot retrieval device of the invention;

FIGS. 68a-68b illustrate another clot retrieval device of the invention;

FIGS. 69a-69b illustrate a further clot retrieval device of the invention; and

## DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Specific embodiments of the present invention are now described in detail with reference to the figures, wherein similar reference numbers indicate identical or functionality similar elements. The terms “distal” or “proximal” are used in the following description with respect to a position or direction relative to the treating physician. “Distal” or “distally” are a position distant from or in a direction away from the physician. “Proximal” or “proximally” or “proximate” are a position near or in a direction toward the physician.

The following detailed description is merely exemplary in nature and is not intended to limit the invention or the application and uses of the invention. Although the description of the invention is in the context of treatment of blood arteries such as the carotid and lung arteries, the invention may also be used in any other vessels where it is deemed useful.

As shown generally in FIGS. 1a-1b and 2a-2h, an obstructive clot 2 is occluding a cerebral artery 1 and a guidewire 3 is inserted into the artery 1 using conventionally known techniques. The guidewire 3 is advanced across the clot 2 and then a microcatheter 4 is advanced over the guidewire 3 to a location distal to the clot 2. The mechanical clot retrieval device 10 of the present invention is advanced through the microcatheter 4 and across the clot 2. The retrieval device 10 has an elongate member 11 having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, and a plurality of ring elements 12 configured at the distal end of the elongate member. The ring elements 12 are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements 12 toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by the elongate member 11. When the retrieval device 10 is advanced through the microcatheter 4, the ring elements are in the collapsed configuration substantially parallel to the longitudinal axis of the elongate member 11. Each ring element 12 comprising a plurality of struts 13 is made of self expanding material such as nitinol and is interconnected by ring connecting tethers 14. The microcatheter 4 is retracted after the retrieval device 10 is positioned within or distal of the clot 2 to allow ring elements 12 to deploy and expand. When the ring elements 12 deploy and expand, the struts 13 engage or capture the clot 2 in the ring elements 12 and the retrieval device 10 is retracted proximally out of the artery 1.

FIGS. 3a-3d illustrates one of the preferred embodiments of a mechanical clot retrieval device 20 of the present invention. The retrieval device 20 has an elongate member 21 having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, and a plurality of ring elements 22 configured at the distal end of the elongate member 21. The ring elements 22 are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements 22 toward the expanded configuration. In the

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collapsed configuration, the radial force is absorbed by the elongate member 21. Each ring element 22 comprising a plurality of struts 23 is made of shape memory material Nitinol and is interconnected by ring connecting tethers 24. Each strut 23 has a crown element 27 with an engagement member 29 and a fixed tab 30. The crown element 27 holds the neighboring crown element 27 in a snap-fit mechanism 28 to restrain the ring elements 22 in the collapsed configuration substantially parallel to the longitudinal axis of the elongate member 21. Two pull tethers 25 which have distal ends that are attached to most proximal ring element 22, and proximal ends that extend exterior of the artery for maneuvering and control by the physician, are present. The snap-fit mechanism 28 restrains the retrieval device 20 in the collapsed configuration when advancing through a microcatheter 4.

FIGS. 4a-4d shows a method of using the retrieval device 20 in accordance with the preferred embodiment as shown in FIGS. 3a-3d. A guidewire (not shown) is inserted in the cerebral artery 1 and is advanced distally across an obstructive clot 2. A microcatheter 4 is advanced over the guidewire to a location proximal to the clot and then the retrieval device 20 of the present invention is advanced through the microcatheter 4 to the clot in the collapsed configuration. The retrieval device 20 has an elongate member 21 having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, and a plurality of ring elements 22 configured at the distal end of an elongate member 21. The ring elements 22 are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements 22 toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by the elongate member 21. When the retrieval device 20 is advanced through the microcatheter 4, the ring elements are in collapsed configuration substantially parallel to the longitudinal axis of the elongate member 21. Each ring element 22 comprises a plurality of struts 23 and is made of shape memory material nitinol and is interconnected by ring connecting tethers 24. The microcatheter 4 is retracted when the retrieval device 20 is positioned within or distal of the clot 2 to allow ring elements 22 to reach the expanded configuration. The pull tethers 25 attached to the retrieval device 20 allow the physician to manually disengage the snap-fit mechanism 28. The ring elements 22 engage or capture the clot 2 from the distal surface of the clot 2 and retract the clot 2 proximally towards the microcatheter 4. The microcatheter 4 is re-advanced to reduce the expanded configuration of the proximal end of the device 20 in order to retrieve it more easily from the artery 1.

FIGS. 5a-5d shows a mechanical clot retrieval device 40 of the present invention which is a slight variant of the embodiment of the retrieval device as shown in FIGS. 3a-3d. The retrieval device 40 has an elongate member 41 having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements 42 configured at the distal end of the elongate member 41, and a proximal collar 51. The ring elements 42 are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements 42 toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by the elongate member 41. Each ring element 42 comprising a plurality of struts 43 and is made of shape memory material Nitinol and is interconnected by ring connecting tethers 44. Also present are a pair of pull tethers 45, having distal ends which are attached to the most

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proximal ring element 42 and the proximal ends are attached to the elongate member 41. Each strut 43 has a crown element 47 with an engagement member 49 and an engagement hook 50. Each crown element 47 holds the neighboring crown element 47 in a snap-fit mechanism 48 which restrains the ring elements 42 in the collapsed configuration substantially parallel to the longitudinal axis of the elongate member 41. The snap-fit configuration 48 restrains the retrieval device 40 in the collapsed configuration when advancing through the microcatheter 4.

Another embodiment of the mechanical clot retrieval device of the present invention, which is similar to the one shown in FIGS. 3a-3d, is illustrated in FIGS. 6a-6f. The retrieval device 60 has an elongate member 61 having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, and a plurality of ring elements 62 configured at the distal end of the elongate member 61. The ring elements 62 are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements 62 toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by the elongate member 61. Each ring element 62, comprising a plurality of struts 63, is made of shape memory material Nitinol and is interconnected by ring connecting tethers 64. Each strut 63 has a crown element 67 with an engagement member 68. Each engagement member 68 holds the neighboring crown element 67 in a snap-fit mechanism which restrains the ring elements 62 in the collapsed configuration substantially parallel to the longitudinal axis of the elongate member 61. A pair of pull tethers 65 are attached, having distal ends which are attached to each connector (not labeled) of the crown element 67, and proximal ends which extend exterior of the artery for manipulation and control by the physician. The snap-fit mechanism restrains the retrieval device 60 in the collapsed configuration as it is advancing through the microcatheter 4. The pull tethers 65 may be used to manually disengage the snap-fit mechanism and allow the retrieval device 60 reach the expanded configuration.

Another embodiment of the mechanical clot retrieval device of the present invention, which is largely similar to the one shown in FIGS. 3a-3d, is illustrated in FIGS. 7a-7f. The retrieval device 80 has an elongate member 81 having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, and a plurality of ring elements 82 configured at the distal end of the elongate member 81. The ring elements 82 are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements 82 toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by the elongate member 81. Each ring element 82, comprising a plurality of struts 83, is made of shape memory material Nitinol and is interconnected by ring connecting tethers 84. Each strut 83 has a crown element 87 with an engagement member 89 and an engagement tab 88. Each crown element 87 holds the neighboring crown element 87 in a snap-fit mechanism which restrains the ring elements 82 in the collapsed configuration substantially parallel to the longitudinal axis of the elongate member 81. A pair of pull tethers 85 is attached, having distal ends which are attached to each engagement tab 88 of the crown element 87, and proximal ends which extend exterior of the artery for manipulation and control by the physician. The snap-fit mechanism restrains the retrieval device 80 in the collapsed configuration as it is advancing through the microcatheter 4. The pull tethers 85 may be used

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to manually disengage the snap-fit mechanism and allow the retrieval device **80** to reach the expanded configuration.

Another preferred embodiment of the mechanical clot retrieval device **100** of the present invention is illustrated in FIGS. **8a-8d**. The retrieval device **100** includes an elongate member **101** having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements **102** arranged at the distal end of the elongate member **101**, a fixed proximal collar **111** and a distal moveable collar **110**. The ring elements **102** are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements **102** toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by the elongate member **101**. Each ring element **102** comprising a plurality of struts **103** is made of shape memory material nitinol and is interconnected by ring connecting tethers **104**. Each strut **103** has a hook lock **107** with first lock **108** and second lock **109**. Each hook lock **107** holds the neighboring hook lock **107** in a snap-fit mechanism to restrain the ring elements **102** in the collapsed configuration substantially parallel to the axis of the elongate member **101**. There are pair of pull tethers **105** attached, having distal ends which are attached to the distal collar **110**, and proximal ends that extend exterior of the artery for maneuvering and control by the physician. The snap-fit mechanism restrains the retrieval device in the collapsed configuration when advancing through the microcatheter **4**. The distal collar **110** is pulled proximally by the pull tether **105** to manually disengage and allow ring elements **102** reach an expanded configuration.

FIGS. **9a-9d** shows a mechanical clot retrieval device **120** of the present invention, which is a slight variant of the embodiment of the retrieval device **100** as shown in FIGS. **8a-8d**; the only difference is use of a balloon **125** in place of the distal moveable collar **110**. The retrieval device **120** has an elongate member having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements **122** configured at the distal end of the elongate member **121**, a proximal collar **126** and a balloon **125**. The ring elements **122** are self-expandable from a collapsed configuration to an expanded configuration and have a radial force that biases the ring elements **122** toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by the elongate member **121**. Each ring element **122** comprises a plurality of struts **123** and is made of shape memory material nitinol and is interconnected by ring connecting tethers **124**. Each strut **123** has a hook lock **127** with a first lock **128** and a second lock **109**. Each hook lock **127** holds the neighboring hook lock **127** in a snap-fit mechanism to restrain the ring elements **122** in the collapsed configuration. The balloon **125** is in a collapsed state when the device **20** is advanced through the microcatheter **4**. The balloon **125** is inflated to disengage and allow ring elements **122** to reach the expanded configuration.

Another embodiment of a mechanical clot retrieval device **140** of the present invention is largely similar to the one shown in FIGS. **8a-8d**, and is shown in FIGS. **10a-10d**; with the main difference being the use of a ball element **145** in place of the distal movable collar **110**. The retrieval device **140** has an elongate member **141** having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements **142** configured at the distal end of the elongate member **141**, a proximal collar **150** attached to a push tube **146**, and a ball element **145**. The ring elements **142** are self-expandable

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from a collapsed configuration to an expanded configuration and feature a radial force that biases the ring elements **142** toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by the elongate member **141**. Each ring element **142**, comprising a plurality of struts **143**, is made of shape memory material nitinol and is interconnected by ring connecting tethers **144**. Each strut **143** has a hook lock **147** with a first lock **148** and a second lock **149**. Each hook lock **147** holds the neighboring hook lock **147** in a snap-fit mechanism to restrain the device **140** in the collapsed configuration. The ball element **145** is manually pulled proximally through the device **140** to force apart the ring elements **142** which subsequently form the expanded configuration.

FIGS. **11a-11h** shows another preferred embodiment of a mechanical clot retrieval device of the present invention. The retrieval device **160** includes an elongate member **161** having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, and a plurality of ring elements **162** attached to the elongate member **161** by connecting tethers **164** at connection points **165**. The ring elements **162** are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements **162** toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by the elongate member **161**. Each ring element **162**, comprising a plurality of struts **163**, is made of shape memory material nitinol. Each strut **163** features a crown element **169**, which includes a proximal ring crown **167** and a distal ring crown **166**. The connecting tether **164** connects the proximal ring crown **167** with the elongate member **161**. The crown element **169** engages with the elongate member **161** in a snap-fit mechanism to restrain the ring elements **162** in the collapsed configuration. The snap-fit mechanism **168** restrains the retrieval device **160** in the collapsed configuration as it advances through a microcatheter **4**. The microcatheter **4** is retracted proximally to disengage and allow the ring elements **162** to reach the expanded configuration. The elongate member **161** is manually retracted to disengage the snap-fit mechanism.

Another embodiment of a mechanical clot retrieval device of the present invention is illustrated in FIGS. **12a-12c**. A guidewire is inserted inside a cerebral artery **501** using conventional techniques. The guidewire is advanced across an obstructive clot **502** and then an intravascular microcatheter **504** is advanced over the guidewire to a location proximal to the clot **502**. The retrieval device **520** has an elongate member having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, and a plurality of ring elements **522** configured at the distal end **526** of the elongate member **521**. The ring elements **522** are self-expandable from a collapsed configuration to an expanded configuration and have a radial force that biases the ring elements **522** towards the expanded configuration. Each ring element **522**, comprising a plurality of struts **523**, is made of shape memory material nitinol and is interconnected by ring connecting tethers **524**. Each strut **523** has a crown element **527** attached to the elongate member **521** by a bonding agent **528** to restrain the ring elements **522** in the collapsed configuration. The radial force is absorbed by the bonding agent **528** to restrain the retrieval device **520** in the collapsed configuration when the device is advancing through the microcatheter **504**. The bonding agent **528** is dissolved in vivo to disengage and allow the ring elements **522** to reach the expanded configuration. The device has a pair of pull tethers **525**, having distal ends

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which are attached to most proximal ring element **522** and proximal ends that extend out of the artery for maneuvering and control by the physician.

FIGS. **13a-13f** shows a slight variant embodiment of a mechanical clot retrieval device of the present invention, largely similar to the one shown in FIGS. **12a-12c**. The difference between the two is the use of a soluble covering **548** in place of the bonding agent **528**. The retrieval device **540** has an elongate member, having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, and a plurality of ring elements **542** configured at the distal end **546** of the elongate member **541**. The ring elements **542** are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force biasing the ring elements **542** towards the expanded configuration. Each ring element **542**, comprising a plurality of struts **543**, is made of shape memory material nitinol and is interconnected by ring connecting tethers **544**. Each strut **543** has a crown element **547** attached to the elongate member **541** by a re-absorbable covering **548** to restrain the ring elements **542** in the collapsed configuration. The radial force is absorbed by the re-absorbable covering **548** to restrain the retrieval device **540** in the collapsed configuration when it is advancing through the microcatheter (not shown). The re-absorbable covering **548** is dissolved in vivo to disengage and allow the ring elements **542** to reach the expanded configuration. The device features a pair of pull tethers **545**, having distal ends which are attached to the most proximal ring element **542** and proximal ends that extend out of the artery for maneuvering and control by the physician.

Another preferred embodiment of a mechanical clot retrieval device of the present invention is shown in FIGS. **14a-14c**. The retrieval device **1020** includes an elongate member **1021** having a distal end that extends interior of the artery, a proximal end that extends exterior of the artery and a plurality of radial pins **1028**, and a plurality of ring elements **1022** configured at the distal end **1026** of the elongate member **1021**. The ring elements **1022** are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases ring elements **1022** towards the expanded configuration. Each ring element **1022**, comprising a plurality of struts, is made of shape memory material nitinol and each strut **1023** contains a crown element **1027** with an eyelet **1024**. The distal eyelet **1024** engages with the radial pin **1028** by an engagement element **1029** to fasten the ring elements to the elongate member, whereas proximal eyelets **1024** engage with engagement members **1029** of radial pins **1028** in a snap-fit mechanism to restrain the ring elements **1022** in the collapsed configuration. The ring elements **1022** may be connected to the elongate member **1021** by ring connecting tethers (not shown). The snap-fit mechanism restrains the retrieval device **1020** in the collapsed configuration when advancing through the microcatheter (not shown).

FIGS. **15a-15c** and **16a-16d** show a method for using a mechanical clot retrieval device **1040** in accordance with the preferred embodiment shown in FIGS. **14a-14c**. A guidewire **1003** is inserted in a cerebral artery **1001** and is advanced across an obstructive clot **1002**. An intravascular microcatheter **1004** is advanced over the guidewire **1003** to a location proximal to the clot **1002** and then a mechanical clot retrieval device **1004** is advanced through the microcatheter **1004** to the clot **1002** in a collapsed configuration. The retrieval device **1004** includes an elongate member **1041** having a distal end that extends interior of the artery, a proximal end that extends exterior of the artery and a

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plurality of radial pins **1048**, and a plurality of ring elements **1042** arranged at the distal end **1046** of the elongate member **1041**. The ring elements **1042** are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements **1042** toward the expanded configuration. Each ring element **1042**, comprising a plurality of struts **1043**, is made of shape memory material nitinol and each strut features a crown element **1047** with an eyelet **1044**. The eyelets **1044** engage with the radial pins **1048** to attach the ring elements to the elongate member. The radial force is absorbed by radial pins to restrain the ring elements **1042** in the collapsed configuration. When microcatheter **1004** is retracted the ring elements **1042** are able to expand and disengage eyelets **1044** from pins **1048** and are thus freed to expand towards the fully expanded configuration. The ring elements **1042** engage or capture the clot and the device can then be retracted proximally and removed from the artery. In one embodiment the ring elements are connected to the elongate member **1041** by tether elements **1045** as shown in FIGS. **16c** and **16d**.

Another preferred embodiment of a mechanical clot retrieval device of the present invention is illustrated in FIGS. **17a-17d**. The retrieval device **1520** includes an elongate member **1521** having a distal end that extends interior of the artery, a proximal end that extends exterior of the artery, an outer tube **1530** with a plurality of slots **1532** and a retractable inner core wire **1531** which has a proximal end that extends exterior of the artery, and a plurality of ring elements **1522** configured at the distal end of the elongate member **1521**. The ring elements **1522** are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements **1522** toward the expanded configuration. Each ring element **1522** comprising a plurality of struts **1523** is made of shape memory material nitinol and is interconnected by ring connecting tethers **1525**. Each strut **1523** has a crown element **1527** with an eyelet **1524**. A tether is advanced out of the slot **1532** to loop **1528** through the eyelet **1524** and advanced back in the slot **1532** to loop **1526** around the core wire **1531** to engage each ring element **1522** to the elongate member **1521** in a tether-loop mechanism. The radial force is absorbed by the tether-loop mechanism to restrain the retrieval device **1520** in the collapsed configuration when advancing through a microcatheter (not shown). The core wire **1531** is retracted proximally thus disengaging and allowing each ring element **1522** reach the expanded configuration.

FIGS. **18a-18c** depict a mechanical clot retrieval device **1540** of the present invention which is a variant of the retrieval device **1520** as illustrated in FIGS. **17a-17d**. FIG. **18d** is a view of a cross-section through line **1553** of FIG. **18b**. The retrieval device **1540** includes an elongate member **1541** having a distal end that extends interior of the artery, a proximal end that extends exterior of the artery, an outer tube **1550** with a plurality of slots **1552** and a retractable inner core wire **1551** having proximal end **1549** that extends exterior of the artery, and a plurality of ring elements **1542** arranged at the distal end of the elongate member **1541**. The ring elements **1542** are self-expandable from a collapsed configuration to an expanded configuration and have a radial force that biases the ring elements **1542** toward the expanded configuration. Each ring element **1542**, comprising a plurality of struts **1543**, is made of shape memory material nitinol and is interconnected by ring connecting tethers (not shown). Each strut **1543** has a crown element **1547** with an eyelet **1544**. The core wire **1551** is advanced

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out of each slot **1552** to loop **1546** through each eyelet **1544** and advanced back in the slot **1552** to loop inside the outer tube **1550** to engage each ring element **1542** to the elongate member **1541** in a tether-loop mechanism. The radial force is absorbed by the tether-loop mechanism to restrain the retrieval device **1540** in the collapsed configuration when advancing through a microcatheter (not shown). The core wire **1551** is retracted in order to disengage and allow each ring element **1542** reach the expanded configuration.

FIGS. **19a-19d** represents a mechanical clot retrieval device of the present invention which is yet another slightly variant embodiment of the retrieval device **1520** as illustrated in FIGS. **17a-17d**. The retrieval device **1560** includes an elongate member **1561** having a distal end **1569** that extends interior of the artery, a proximal end that extends exterior of the artery and a tube lumen **1570** with a plurality of slots **1571**, and a plurality of ring elements **1562** configured at the distal end of the elongate member **1561**. The ring elements **1562** are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements **1562** toward the expanded configuration. Each ring element **1562**, comprising a plurality of struts **1563**, is made of shape memory material nitinol and is interconnected by ring connecting tethers **1565**. Each strut **1563** has a crown element **1568** with an eyelet **1564**. A plurality of tethers **1566** is positioned within the lumen **1570** and is advanced out of each slot **1571** to loop **1567** each eyelet **1564** and is attached at a distal end **1569** of the elongate member **1561** to engage each ring element **1562** to the elongate member **1561** in a tether-loop mechanism. The radial force is absorbed by the tether-loop mechanism to restrain the retrieval device **1560** in the collapsed configuration when advancing through a microcatheter (not shown). The tethers **1566** are broken or cut to disengage and allow each ring element **1562** reach an expanded configuration.

FIGS. **20a-20b** shows a mechanical clot retrieval device **1580** of the present invention. The retrieval device **1580** includes an elongate member **1581**, a distal end **1569** that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements **1582** configured at the distal end of the elongate member **1581** and a proximal collar **1589** attached to an abutment tube **1588**. The ring elements **1582** are self-expandable from a collapsed configuration to an expanded configuration and feature a radial force that biases the ring elements **1582** toward the expanded configuration. Each ring element **1582**, comprising a plurality of struts **1583**, is made of shape memory material nitinol and is attached to the elongate member **1581** by connecting tethers **1585**. Each strut **1583** has a crown element **1587**. A tether is wrapped around each ring element **1582** and is attached to the elongate member **1581** by a tether loop **1584** to engage each ring element **1582** to the elongate member **1581** in a tether-loop mechanism. The radial force is absorbed by the tether-loop mechanism to restrain the retrieval device **1580** in the collapsed configuration when it is advancing through a microcatheter (not shown). The elongate member **1581** is retracted proximally thus sliding the tether loop **1584** off the ring element **1582** and disengaging and therefore allowing each ring element **1582** reach the expanded configuration.

Another preferred embodiment of a mechanical clot retrieval device of the present invention is illustrated in FIGS. **21a-21f**. The retrieval device **2020** includes an elongate member **2021** having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements **2022** configured at the

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distal end of the elongate member **2021**, and a plurality of beveled **2029** or recessed **2028** collars **2026** configured at distal and proximal ends of each ring element **2022**. The ring elements **2022** are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements **2022** toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by collars **2026**. Each ring element **2022**, comprising a plurality of struts **2023**, is made of shape memory material nitinol and is interconnected by tethers (not labeled) and attached to the elongate member **2021** by ring connecting tethers **2025**. Each strut **2023** includes a crown element **2027** with a tab **2024** extending axially and radially inward and may be bevel or square shape in shape. The tab **2024** engages with the collar **2026** to restrain the ring element **2022** to the elongate member **2021** in a collar mechanism. The collar mechanism restrains the retrieval device **2020** in the collapsed configuration when advancing through a microcatheter (not shown). The elongate member **2021** is retracted proximally to disengage it and allow each ring element **2022** reach the expanded configuration.

FIGS. **22a-22d** shows a method for using the device **2020** in accordance with the preferred embodiment shown in FIGS. **21a-21f**. A guidewire (not shown) is inserted in a cerebral artery **2000** and is advanced across an obstructive clot **2001**. An intravascular microcatheter **2003** is advanced over the guidewire to a location proximal to the clot **2001** and then a mechanical clot retrieval device **2020**, sheathed within a bumper tube **2030**, is advanced through the microcatheter **2003** to the clot **2001** in a collapsed configuration. The microcatheter **2003** is retracted when the retrieval device **2020** is located distal of the clot. It is unsheathed to allow ring elements **2022** to reach the expanded configuration. The elongate member **2021** of the retrieval device **2020** allows the physician to manually disengage the collar mechanism and the ring connecting tether **2025** attached to the elongate member **2021**. The ring elements **2022** engage or capture the clot **2001** from the distal surface of the clot **2001** and retract the clot **2001** proximally to the microcatheter **2003**.

FIGS. **23a-23c** depicts a mechanism used in a mechanical clot retrieval device **2040** for engaging a tab **2044** with a collar **2046** in a slight variant with the preferred embodiment shown in FIGS. **21a-21f**. The retrieval device **2040** includes an elongate member **2041** having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a ring element **2042** configured at the distal end of the elongate member **2041** and a proximal collar **2046**. The ring element **2042** is self-expandable from a collapsed configuration to an extended configuration and has a radial force that biases the ring element **2042** toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by the proximal collar **2046**. The ring element **2042**, comprising plurality of struts **2043**, is made of shape memory material nitinol and each strut **2043** has a crown element **2047** with a tab **2044** extending axially and radially inward. The tab **2044** is shaped to engage with the collar **2046**, having a recess to restrain the ring element **2042** to the elongate member **2041** in a collar mechanism. The collar mechanism restrains the retrieval device **2040** in the collapsed configuration when advancing through a microcatheter (not shown). The elongate member **2041** is retracted proximally to disengage it and allow each ring element **2042** reach the expanded configuration.

FIGS. **24a-24c** shows a mechanical clot retrieval device **2060** of the present invention which is a slightly variant embodiment of the retrieval device **2020** as illustrated in

FIGS. 21a-21f. The retrieval device 2060 includes an elongate member 2061 having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements 2062 configured at the distal end of the elongate member 2061, and a plurality of collars 2066 having a plurality of holes 2068 configured proximally of each ring element 2062. The ring members 2062 are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements 2062 toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by collars 2066. Each ring element 2062, comprising a plurality of struts 2063, is made of shape memory material nitinol and is interconnected by ring connecting tethers 2069. Each strut 2063 has a crown element 2067 with a pin 2064 extending axially and radially inward. The pin 2064 engages with the hole 2068 to restrain the ring elements 2062 to the elongate member 2061 in a collar mechanism. The device includes a pair of cables 2065 having distal ends which are attached to the most proximal ring element 2062 and proximal ends that extend exterior of the artery for manipulation and control by the physician. The collar mechanism restrains the retrieval device 2060 in the collapsed configuration when it is advancing through a microcatheter 2003. The cables 2065 are manually pulled proximally to disengage the collar mechanism and allow each ring element 2062 reach the expanded configuration.

FIGS. 25a-25k represents a mechanical clot retrieval device 2080 of the present invention which is another slightly variant embodiment of the retrieval device 2020 as illustrated in FIGS. 21a-21f. The retrieval device 2080 includes elongate member 2081a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements 2082 configured at the distal end of the elongate member 2081, and a plurality of shaped engagement collars 2085 having a plurality of dove tail grooves 2088 configured proximally of each ring element 2082. The ring elements 2082 are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements 2082 toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by collars 2085. Each ring element 2082, comprising a plurality of struts 2083, is made of shape memory material nitinol and is attached to the elongate member 2081 by tethers 2089. Each strut 2083 has a crown element 2087 with a shaped tab 2084 extending axially and radially inward. The shaped tab 2084 engages with the shaped engagement collar 2085 to restrain the ring element 2082 to the elongate member 2081 in a collar mechanism. The collar mechanism restrains the retrieval device 2080 in the collapsed configuration when it is advancing through a microcatheter (not shown). The elongate member 2081 is manually retracted proximally to disengage it and allow each ring element 2082 reach the expanded configuration.

FIGS. 26a-26c represents a slightly variant embodiment of the retrieval device 2080 as represented in FIGS. 25a-25k, having additional ring connecting tethers 2101 interconnecting each ring element 2082.

Another preferred embodiment of a mechanical clot retrieval device 2520 of the present invention is illustrated in FIGS. 27a-27b. The retrieval device 2520 includes an elongate member 2521 having a distal end that extends interior of the artery, a proximal end that ends interior of the artery and an inner lumen 2529 with a plurality of openings (not labeled), and a plurality of ring elements 2522 configured at the distal end of the elongate member 2521. The ring

elements 2522 are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases ring elements 2522 toward the expanded configuration. Each ring element 2522, comprising a plurality of struts 2523, is interconnected by ring connecting tethers 2525. Each strut 2523 has a crown element 2527 and an engagement tab 2524. A plurality of tether loops 2526 having proximal ends that extend exterior of the lumen 2529 is advanced out of each opening (not opening) to circle the engagement tab 2524 and engage each ring element 2522 to the elongate member 2521 in an eyelet mechanism. The radial force is absorbed by the eyelet mechanism to restrain the retrieval device 2520 in the collapsed configuration when it is advancing through a microcatheter (not shown). The tethers are manually pulled proximally to disengage them and allow each ring element 2522 to reach the expanded configuration.

FIGS. 28a-28b represents a mechanical clot retrieval device 2540 of the present invention which is a slightly variant embodiment of the retrieval device 2520 as illustrated in FIGS. 27a-27b. The retrieval device 2540 includes an elongate member 2541 having a distal end that extends interior of the artery, a proximal end that extends exterior of the artery and a plurality of raised tabs 2548, and a plurality of ring elements 2542 configured at the distal end of the elongate member 2541. The ring elements 2542 are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements 2542 toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by raised tabs 2548. Each ring element 2542, comprising a plurality of struts 2543, is interconnected by ring connecting tethers 2545. Each strut 2543 has a crown element and an engagement tab 2544. The engagement tab 2544 engages with the raised tab 2548 to restrain the ring element 2542 to the elongate member 2541 in an eyelet mechanism. The eyelet mechanism restrains the retrieval device 2540 in the collapsed configuration when it is advancing through a microcatheter (not shown). The elongate member 2541 is manually retracted proximally to disengage it and allow each ring element 2542 to reach the expanded configuration.

FIGS. 29a-29h shows a method for using a mechanical clot retrieval device 2560 in accordance with the preferred embodiment shown in FIGS. 27a-27b and 28a-28b. A guidewire 2502 is inserted in a cerebral artery 2500 and is advanced through an obstructive clot 2501. An intravascular microcatheter 2503 is advanced over the guidewire 2502 to a location distal to the clot 2501 and then the retrieval device 2560 is advanced through the microcatheter 2503 to the clot 2501 in a collapsed configuration. The microcatheter 2503 is retracted when the retrieval device 2560 is positioned distal of the clot 2501 to allow a plurality of ring elements 2562 to reach an expanded configuration. The ring elements 2562, comprising a plurality of struts 2563, are interconnected by ring connecting tethers 2565. A tether 2564 is attached at a distal end of the retrieval device 2560 and its proximal end extends out of the artery. The elongate member 2561 and tether 2564 allows the physician to manually disengage eyelet mechanism. The ring elements 2562 engage or capture the clot 2501 from the distal end of the clot 2501 and retract the clot 2501 proximally to the microcatheter 2504.

Another embodiment of a mechanical clot retrieval device 3020 of the present invention is illustrated in FIGS. 30a-30e. The retrieval device 3020 includes an elongate member 3021 designed to have a distal end that extends interior of the artery, a proximal end that extends exterior of the artery, a plurality of engagement diameters 3028 and a plurality of



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disengagement diameters **3029**, a plurality of ring elements **3022** configured at the distal end of the elongate member **3021**, and a proximal abutment tube **3031**. The ring elements **3022** are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements **3022** toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by the engagement diameters. Each ring element **3022** comprising a plurality of struts **3023** is interconnected by ring connecting tethers **3025**. Each strut **3023** has a crown element **3027** with a C-shaped engagement tab **3030** extending radially inward. The C-shaped engagement tab **3030** engages with the engagement diameter **3028** to restrain the ring element **3022** to the elongate member **3021** in the collapsed configuration when it is advanced through a microcatheter (not shown). The device features a pair of control tethers **3026** having distal ends which are attached to the crown element **3027** of the most proximal ring element **3022**. The axial movement of the elongate member **3021** disengages each ring element **3022** at the disengagement diameter **3029** and allows each ring element **3022** to reach the expanded configuration.

FIGS. **31a-31e** shows a mechanical clot retrieval device **3040** of the present invention which is a slightly variant embodiment of the retrieval device **3020** as illustrated in FIGS. **30a-30e**. The retrieval device **3040** includes an elongate member **3041** having a distal end that extends interior of the artery, a proximal end that extends exterior of the artery and an inner wire **3051**, a plurality of ring elements **3042** arranged at a distal end of the elongate member **3041**, and a proximal abutment tube **3052**. The ring elements **3042** are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements **3042** toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by the elongate member having inner wire **3051**. Each ring element **3042** comprising a plurality of struts **3042** is interconnected by ring connecting tethers **3045**. Each strut **3043** has a crown element **3047** with a C-shaped engagement tab **3050** extending radially inward. The C-shaped engagement tab **3050** engages with the elongate member **3041**. The inner wire **3051** restrains the retrieval device **3040** in the collapsed configuration when it is advanced through a microcatheter (not shown). The device features a pair of control tethers **3046** having distal ends which are attached to the crown element **3047** of the most proximal ring element **3042** and proximal ends which are attached to the abutment tube **3052**. The withdrawal of the inner wire **3051** disengages it and allows each ring element **3042** reach the expanded configuration.

FIGS. **32a-32d** illustrates the mechanical clot retrieval device **3060** of the present invention. The retrieval device **3060** includes an elongate member **3061** having a distal end that extends interior of the artery, a proximal end that extends exterior of the artery and an inner lumen **3071** with a plurality of slots **3070**, a plurality of ring elements **3062** configured at the distal end of the elongate member **3061**, and a proximal collar **3066**. The ring elements **3062** are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements **3062** toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by slots **3070**. Each ring element **3062**, comprising a plurality of struts **3063**, is interconnected by ring connecting tethers **3065**. Each strut **3063** has a crown element **3067** with a stepped engagement tab **3064** extending longitudinally and radially. The engagement tab **3064** engages with

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the slot **3070** to restrain the ring elements **3062** to the elongate member **3061** and to restrain the retrieval device **3060** in the collapsed configuration when it is advanced through a microcatheter (not shown). A pair of control tethers **3068** is attached from the crown element **3067** of the most proximal ring element **3062**, to the proximal collar **3066**. The proximal collar **3066** is manually pulled proximally to disengage it and allow the ring elements **3062** to reach an expanded configuration.

FIGS. **33a-33g** represents another embodiment of a mechanical clot retrieval device of the present invention. The retrieval device **3080** includes an elongate member **3081** having a distal end that extends interior of the artery, a proximal end that extends exterior of the artery and a plurality of monofilaments **3088**, a plurality of ring elements **3082** configured at the distal end of the elongate member **3081**, and a proximal collar **3086**. The ring elements **3082** are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force biasing the ring elements **3082** toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by the monofilaments. Each ring element **3082** comprising a plurality of struts **3083** is interconnected by ring connecting tethers **3085**. Each strut **3082** has a crown element **3087** with a C-shaped engagement tab **3084**. The C-shaped engagement tab **3084** engages with the monofilament **3088** to restrain the ring element **3082** to the elongate member **3081** in a snap-fit mechanism. The snap-fit mechanism restrains the retrieval device **3080** in the collapsed configuration when it is advancing through a microcatheter (not shown). The device contains a pair of control tethers **3089** having distal ends which are attached to the crown element **3087** of the most proximal ring element **3082** and proximal ends which are attached to the collar **3086**. The elongate member **3081** is manually retracted to disengage it and allow each ring element **3082** reach the expanded configuration.

Another embodiment of a mechanical clot retrieval device of the present invention is shown in FIGS. **34a-34j**. The retrieval device **3100** includes an elongate member **3101** having a distal end that extends interior of the artery, a proximal end that extends exterior of the artery and a plurality of inactivated cuffs **3108a** configured at the distal end of the elongate member **3101**, a plurality of ring elements **3102** configured over the cuff **3108a**, and a tube **3106**. Each cuff **3108a** is made of electro-active polymer which swells to an activated state **3108b** when current is applied. The ring elements **3102** are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force biasing the ring elements **3102** toward the expanded configuration. Each ring element **3102** comprising a plurality of struts **3103** is interconnected by ring connecting tethers **3105**. Each strut has a crown element **3107**. A pair of control tethers **3104** are attached to the crown element **3107** of the most proximal ring element **3102**, having proximal ends that extend out of the artery. A ring restraining tether **3109** is wrapped around each ring element **3102** restraining it to the elongate member **3101** in the collapsed configuration when it is advanced through a microcatheter (not shown). In the collapsed configuration, the radial force is absorbed by the ring restraining tethers **3109**. The current is applied through the restraining tether **3109** to allow each cuff **3108a** to reach activated state **3108b** and then they are manually pulled proximally to disengage them and allow each ring element **3102** reach the expanded configuration.

FIGS. **35a-35b** represents another embodiment of a mechanical clot retrieval device of the present invention.

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The retrieval device **3120** includes an elongate member **3121** having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements **3122** configured at the distal end of the elongate member **3121**, a proximal collar **3129**, and a bumper tube **3126**. The ring elements **3122** are self-expandable from a collapsed configuration to an expanded configuration and have a radial force biasing the ring elements **3122** toward the expanded configuration. Each ring element **3122**, comprising a plurality of struts **3123**, is interconnected by ring connecting tethers **3125**. Each strut **3123** has a crown element **3127** with an eyelet **3128**. A tether loop **3130** engages each ring element **3122** to the elongate member **3121** to restrain the retrieval device **3120** in the collapsed configuration when it is advancing through a microcatheter **3003**. In the collapsed configuration, the radial force is absorbed by tether loops **3130**. The device contains a pair of control tethers **3124**, having distal ends which are attached to the crown element **3127** of the most proximal ring element **3122** and proximal ends which extend out of the artery. The elongate member **3121** is manually retracted proximally to disengage it and allow each ring element **3122** reach the expanded configuration.

Another embodiment of a mechanical clot retrieval device of the present invention is shown in FIGS. **36a-36d**. The retrieval device **3140** includes an elongate member **3141** having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements **3142** arranged at the distal end of the elongate member **3141**, a bumper tube **3146** and a proximal collar **3149**. The ring elements **3142** are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force biasing ring elements toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by the elongate member **3141**. Each ring element **3142** comprising a plurality of struts **3143** is interconnected by ring connecting tethers **3145**. Each strut **3143** has a crown element **3147** with an engagement tab **3148** having an eyelet **3144**. The elongate member **3141** passes through each eyelet **3144** engaging each ring element **3142** to the elongate member **3141** to restrain the retrieval device **3140** in the collapsed configuration when it is advancing through a microcatheter **3003**. The elongate member **3141** is manually retracted proximally to disengage it and allow each ring element **3142** reach the expanded configuration.

FIGS. **37a-37i** represents a mechanical clot retrieval device of the present invention which is a slightly variant embodiment of the retrieval device **3140** as shown in FIGS. **36a-36d**. The retrieval device **3160** includes an elongate member **3161** having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements **3162** configured at the distal end of the elongate member **3161**, a bumper tube (not labeled) and a proximal collar (not labeled). The ring elements **3162** are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force biasing the ring elements **3162** toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by the elongate member **3161**. Each ring element **3162** comprising a plurality of struts **3163** is interconnected by ring connecting tethers (not labeled). Each strut has a crown element **3167** with an engagement tab **3166** and an eyelet **3168**. The elongate member **3161** passes through each eyelet **3168** engaging each ring element **3162** to the elongate member **3161** to restrain the retrieval device **3160** in the collapsed configuration when it is advancing through a

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microcatheter **3003**. The elongate member **3161** is manually retracted proximally to disengage and allow each ring element **3162** reach the expanded configuration.

Another embodiment of a mechanical clot retrieval device of the present invention is illustrated in FIGS. **38a-38d**. The retrieval device **3200** has an elongate member **3201** having a distal end that extends interior of the artery, a proximal end that extends exterior of the artery and a plurality of restraining loops **3206** configured at the distal end of the elongate member **3201**, and a plurality of ring elements **3202** arranged at the distal end of the elongate member **3201**. The ring elements **3202** are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements **3202** toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by the restraining loops **3206**. Each ring element **3202** comprising a plurality of struts **3203** is connected to the loop **3206** by connecting tethers **3205**. Each strut **3203** is having a crown element **3207**. The device features a pair of control tethers **3204**, having distal ends which are attached to the crown element **3207** of the most proximal ring element **3202**, and proximal ends that extend out of the artery. The loops **3206** engage the ring elements **3202** to the elongate member **3201** in an offset loop mechanism. The offset loop mechanism restrains the retrieval device **3200** in the collapsed configuration when it is advanced through a microcatheter (not shown). The elongate member **3201** is manually retracted proximally to disengage it and allow each ring element **3202** to reach the expanded configuration.

Another embodiment of a mechanical clot retrieval device **3300** of the present invention is illustrated in FIGS. **39a-39d**. The retrieval device **3300** has an elongate member **3301** having a distal end that extends interior of the artery and a proximal end that extend exterior of the artery, a plurality of ring elements **3302** arranged at the distal end of the elongate member **3301**, a bumper tube **3306**, and a proximal collar **3308**. The ring elements **3302** are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by the elongate member **3301**. Each ring element **3302**, comprising a plurality of struts **3303**, is interconnected by ring connecting tethers **3305**. Each strut **3303** has a crown element **3307**. The device has comprises a pair of control tethers **3304**, having distal ends which are attached to the crown element **3307** of the most proximal ring element **3302** and proximal ends that are attached to the bumper tube **3306**. The crown element **3307** of each strut **3303** is confined around the elongate member **3301** to restrain the ring element **3302** to the elongate member **3301** when it is advanced through a microcatheter **3309**. The elongate member **3301** is retracted proximally to disengage it and allow each ring element **3302** to reach the expanded configuration.

FIGS. **40a-40e** and **41a-41d** shows a method of advancing a mechanical clot retrieval device **3405** in accordance with a preferred embodiment of the present invention in a tortuous vessel **3400**. A guidewire **3402** is inserted in the vessel **3400** and is advanced through an obstructive clot **3401**. An intravascular microcatheter **3403** is advanced over the guidewire to a location distal to the clot **3401** and then the retrieval device **3405** is advanced through the microcatheter **3403** to the clot **3401** in a collapsed configuration. The microcatheter **3403** is retracted to allow the plurality of ring elements (not labeled) to reach an expanded configuration. The ring elements (not labeled) contain a plurality of struts

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(not labeled). Each ring element is connected to the next ring element (not labeled) by a ring connecting tether **3406**. A control tether **3407** is attached to the strut (not labeled) of the proximal ring element having a proximal end that extends out of the patient to allow physician to manually maneuver the retrieval device **3405**. The retrieval device **3405** engages or captures the clot **3401** from the distal end of the clot **3401** and retracts the clot **3401** proximally into the microcatheter **3403**.

FIGS. **42a-42d**, **43a-43h** and **44a-44b** illustrates the mechanical clot retrieval device **3420** of the present invention. The retrieval device **3420** includes an elongate member **3421** having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, and a plurality of ring elements **3422** configured at the distal end of the elongate member **3421**. The ring elements **3422** are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements **3422** toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by an intravascular microcatheter (not shown) through which the retrieval device **3420** is delivered inside the artery. Each ring element **3422**, comprising a plurality of struts **3423**, is interconnected by ring connecting tethers **3425**. Each strut **3423** has a crown element **3427** with or without a shaped tab **3428** or an eyelet **3426**. The crown element **3427** is connected to neighboring crown element **3427** by the tether **3425** which may be looped around tab **3428** or passed through eyelet **3426**.

The crown element **3427** which is without the shaped tab **3428** or the eyelet **3426** may be connected to neighboring crown element **3427** by an adhesive bond **3429**. Crown-to-crown **3427** connection restrains the retrieval device **3420** in the collapsed configuration when advanced through the intravascular microcatheter (not shown). The device features a pair of removal tethers **3424**, having distal ends which are attached to the crown element **3427** of the most proximal ring element **3422**, and proximal ends that extend out of the artery. The microcatheter is retracted proximally and tether **3424** is manually pulled proximally to disengage it and allow each ring element **3422** reach the expanded configuration.

Another embodiment of a mechanical clot retrieval device of the present invention is represented in FIG. **45**. The retrieval device **3440** has an elongate member **3441** having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements **3442** having a first diameter and a second diameter, and a control strut **3444** having distal end attached to proximal ring element **3442** and proximal end attached to the elongate member **3441** by adhesive bonds **3446**. The ring elements **3442** are self-expandable from a collapsed configuration to an expanded configuration and have a radial force that biases the ring elements **3442** toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by an intravascular microcatheter (not shown) through which the retrieval device **3440** is delivered inside the artery. Each ring element **3442**, comprising a plurality of struts **3443**, is connected by ring connecting tethers **3445**. Each strut **3443** has a crown element **3447**. The crown element **3447** is connected to neighboring crown element **3447** by the tether **3445**. Crown-to-crown connection restrains the retrieval device **3440** in the collapsed configuration when it is advanced through the microcatheter (not shown). The microcatheter is retracted proximally and each ring element **3442** disengages to create a zigzag stent surface for improved clot engagement.

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FIG. **46** represents a mechanical clot retrieval device **3460** of the present invention which is a slightly variant embodiment of the retrieval device as illustrated by FIG. **46**. The retrieval device **3460** has an elongate member **3461** having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements **3462** attached at the distal end of the elongate member and a control strut **3464** having a distal end attached to the most proximal ring element **3462** and a proximal end attached to the elongate member **3461** by adhesive bonds **3466**. The ring elements **3462** are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by an intravascular microcatheter (not shown) through which the retrieval device **3460** is delivered inside the artery. Each ring element **3462**, comprising a plurality of struts **3463**, is connected by ring connecting tethers **3465**. Each strut **3463** has a crown element **3467**. The crown element **3467** is connected to the neighboring crown **3467** by a connecting strut **3468** to restrain the retrieval device **3460** in the collapsed configuration when it is advanced through the microcatheter (not shown). The microcatheter is retracted proximally and each ring element **3462** disengages to create a zigzag stent surface for improved clot engagement.

FIG. **47** represents a mechanical clot retrieval device **3480** of the present invention which is another variant embodiment of the retrieval device as illustrated in FIG. **46**. The retrieval device **3480** has an elongate member **3481** having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements **3482** and a control strut **3484** having a distal end attached to the proximal ring element **3482** and a proximal end attached to the elongate member **3481**. The ring elements **3482** are self-expandable from a collapsed configuration to an expanded configuration and have a radial force that biases the ring elements **3482** toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by an intravascular microcatheter, through which the retrieval device **3480** is delivered inside the artery. Each ring element **3482**, comprising a plurality of struts **3483**, is connected by ring connecting tethers **3485**. Each strut **3483** has a crown element **3487**. The crown element **3487** is connected to the neighboring crown **3487** by the tether **3485** and adhesive bond **3486**. Crown-to-crown connection restrains the retrieval device **3480** in the collapsed configuration when it is advanced through a microcatheter (not shown). The microcatheter is retracted and each ring element **3482** disengages to create a zigzag stent surface for improved clot engagement.

Another preferred embodiment of a mechanical clot retrieval device of the present invention is illustrated in FIGS. **48a-48f**. The retrieval device **3500** includes an elongate member **3501** having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements **3502**, and a pair of removal tethers **3504** having distal ends attached to the proximal ring element **3502** and proximal ends attached to the elongate member **3501**. The ring elements **3502** are self-expandable from a collapsed configuration to an expanded configuration and have a radial force that biases the ring elements **3502** toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by an intravascular microcatheter **3403**, through which the retrieval device **3500** is delivered inside the artery. Each ring element **3502**, comprising a plurality of struts **3503**, is

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interconnected by ring connecting tethers 3505. Each strut 3503 has a crown element 3507. The distally facing crown element 3507 is connected to the neighboring proximally facing crown 3507 by the tether 3505. Crown-to-crown connection restrains the retrieval device 3500 in the collapsed configuration when advanced through the microcatheter 3403. The microcatheter 3403 is advanced inside a tortuous artery 3400 and is positioned distal of an obstructive clot 3401. The microcatheter 3403 is retracted to allow each ring element 3502 reach the expanded configuration and engage or capture the clot 3401 from the distal end of the clot 3401 and the device is then retracted proximally into the microcatheter 3403.

FIGS. 49a-49f represents a mechanical clot retrieval device of the present invention which is a slightly variant embodiment of the retrieval device 3500 as illustrated in FIGS. 48a-48f. The retrieval device has an elongate member 3521 having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements 3522, and a control strut 3524 having a distal end attached to the proximal ring element 3522 and a proximal end attached to the elongate member 3521. The ring elements 3522 are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements 3522 toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by an intravascular microcatheter 3403 through which the retrieval device 3520 is delivered inside the artery. Each ring element 3522, comprising a plurality of struts 3523, is connected by ring connecting tethers 3525. Each strut 3523 has a crown element 3527. The distally facing crown element 3527 is connected to neighboring proximally facing crown 3527 by the tether 3525. Crown-to-crown 3527 connection restrains the retrieval device 3520 in the collapsed configuration when advanced through the microcatheter 3403. The microcatheter 3403 is advanced over a guidewire (not shown) inside a tortuous artery 3400 and positioned distal of an obstructive clot 3401. The microcatheter 3403 is retracted proximally to allow each ring element 3522 reach the expanded configuration and engage or capture the clot 3401 from the distal end of the clot 3401 and the device is then retracted proximally into the microcatheter 3403.

FIGS. 50a-50g shows a mechanical clot retrieval device 3540a of the present invention which is another slightly variant embodiment of the retrieval device 3500 as illustrated in FIGS. 48a-48f. The retrieval device 3540a includes an elongate member 3541 having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements 3542 configured at the distal end of the elongate member 3541 and a plurality of connecting tethers 3545 having distal ends attached to the ring element 3542 and proximal ends attached to the elongate member 3541. The ring elements 3542 are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements 3542 toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by an intravascular microcatheter 3403 through which the retrieval device 3540a is delivered inside the artery. Each ring element 3542 comprising a plurality of struts 3543. Each strut 3543 has a crown element 3547. The distally facing crown element 3547 is connected to neighboring proximally facing crown 3547 by the tether 3545. Crown-to-crown 3547 connection restrains the retrieval device 3540a in the collapse configuration when advanced through a microcatheter 3403. The microcatheter 3403 is advanced over a guidewire

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(not shown) inside a tortuous artery 3400 and positioned distal of an obstructive clot 3401. The microcatheter 3403 is retracted to allow each ring element 3542 to reach the expanded configuration and engage or capture the clot 3401 from the distal base of the clot 3401 and the device is then retracted proximally to the microcatheter 3403.

Another embodiment of a mechanical clot retrieval device 3560 of the present invention is illustrated in FIGS. 51a-51f. The retrieval device 3560 includes an elongate member 3561 having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements 3562 configured at the distal end of the elongate member 3561, a plurality of connecting tethers 3565 having distal ends attached to the ring element 3562 and proximal ends attached to the elongate member 3561, and a pair of removal tethers 3564 having distal ends attached to the most proximal ring element 3562 and proximal ends that extend out of the artery. The ring elements 3562 are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements 3562 toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by an intravascular microcatheter 3403 through which the retrieval device 3560 is delivered inside the artery. Each ring element 3562 comprises a plurality of struts 3563. Each strut 3563 has a crown element 3567. The connecting tether 3565 engages each ring element 3562 to the elongate member 3562 to restrain the retrieval device 3560 in the collapsed configuration when it is advanced through a microcatheter 3403. The microcatheter 3403 is advanced over a guidewire (not shown) inside a tortuous artery 3400 and positioned distal of an obstructive clot 3401. The microcatheter 3403 is retracted to allow each ring element 3562 reach the expanded configuration and engage or capture the clot 3401 from the distal base of the clot 3401 and retracted proximally to the microcatheter 3403.

FIGS. 52a-52d represents a mechanical clot retrieval device 3580 of the present invention which is a slightly variant embodiment of the retrieval device 3560 as illustrated in FIGS. 51a-51f. The retrieval device 3580 has an elongate member 3581 having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements 3582 configured at the distal end of the elongate member 3581 and a plurality of connecting tethers 3585 having distal ends attached to the ring member 3582 and proximal ends attached to the elongate member 3581. The ring elements 3582 are self-expandable from a collapsed configuration to an expanded configuration and comprise a radial force that biases the ring elements 3582 towards the expanded configuration. In the collapsed configuration, the radial force is absorbed by an intravascular microcatheter 3403 through which the retrieval device 3580 is delivered inside the artery. Each ring element 3582 comprises a plurality of struts 3583. Each strut 3583 has a crown element 3587. Each ring element 3582 is wrapped around the elongate member 3581 to restrain the retrieval device 3580 in the collapsed configuration when it is advanced through a microcatheter 3403. The microcatheter 3403 is advanced over a guidewire (not shown) inside a tortuous artery and positioned distal of an obstructive clot 3401. The microcatheter 3403 is retracted to allow each ring element 3582 to reach the expanded configuration and engage or capture the clot 3401 from the distal base of the clot (not shown) and then the device is retracted proximally into the microcatheter 3403.

FIGS. 53a-53f shows a method of using a mechanical clot retrieval device 3600 of the present invention in the embodi-

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ment as illustrated in FIGS. 52a-52d. A guide catheter 3601 is inserted inside the artery and a guidewire (not shown) is advanced within the catheter 3601 bypassing an occlusive clot (not shown). A microcatheter 3602 is advanced over the guidewire (not shown) to a location distal to the clot (not shown) and then the retrieval device 3600 is advanced through the microcatheter 3602 to the clot (not shown) in a collapsed configuration. The microcatheter 3602 is retracted to allow ring elements 3604 to reach an expanded configuration. The ring elements 3604 are self-expandable from the collapsed configuration to the expanded configuration and each ring element comprises plurality of struts 3605. Each strut 3605 has a crown element 3607. The ring elements 3604 are attached to the elongate member 3603 by connecting tethers 3606 and are wrapped around the elongate member 3603 to restrain the retrieval device 3600 in the collapsed configuration when it is advanced through the microcatheter 3602. The ring elements 3604, when expanded, engage or capture the clot (not shown) from the distal base of the clot (not shown) and retract the clot (not shown) proximally to the microcatheter 3602. The retrieval device 3600 returns to the collapsed configuration while retracting into the guide catheter 3601 and is easily removed from the artery.

FIGS. 54a-54h shows another method of using a mechanical clot retrieval device 3620 of the present invention in accordance with the embodiment as illustrated in FIGS. 52a-52d. A guidewire 3404 is inserted in a tortuous artery 3400 and advanced through an obstructive clot 3401. A microcatheter 3403 is advanced over the guidewire 3404 to a location distal to the clot 3401 and then the retrieval device 3620 is advanced through the microcatheter 3403 to the clot 3401 in a collapsed configuration. The microcatheter 3403 is retracted when the retrieval device 3620 is positioned distal of the clot 3401 to allow ring elements 3622 to reach an expanded configuration. The ring elements 3622 are self-expandable from the collapsed configuration to the expanded configuration and are wrapped around the elongate member 3621 to restrain the retrieval device 3620 in the collapsed configuration when advanced through the microcatheter 3403. A removal tether 3624 is attached to the retrieval device 3620. The ring elements 3622, when expanded using an activation element 3626, engage or capture the clot 3401 from the distal base of the clot 3401 and retract the clot 3401 proximally to the microcatheter 3603. The retrieval device 3620 returns to the collapsed configuration while retracting into a guide catheter 3627 and is easily removed from the artery 3400.

Another embodiment of a mechanical clot retrieval device of the present invention is represented in FIG. 55. The retrieval device 3700 has an elongate member 3701 having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements 3702a having a larger diameter and a plurality of ring elements having a smaller diameter 3702b, and a control strut 3704 having distal end attached to proximal ring element 3702a and proximal end attached to the elongate member 3701 by adhesive bonds 3706. The ring elements 3702a and 3702b are self-expandable from a collapsed configuration to an expanded configuration and have a radial force that biases the ring elements 3702a and 3702b toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by an intravascular microcatheter (not shown) through which the retrieval device 3700 is delivered inside the artery. Each ring element 3702a, and 3702b comprises a plurality of struts 3703. Each strut 3703 has a crown element 3707. The crown element

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3707 is connected to neighboring crown element 3707 by the ring to ring connection 3705. The ring to ring connection 3705 restrains the retrieval device 3700 in the collapsed configuration when it is advanced through the microcatheter (not shown). The microcatheter is retracted proximally and each ring element 3702 disengages to form the expanded configuration.

Another embodiment of a mechanical clot retrieval device of the present invention is represented in FIG. 56. The retrieval device 3720 has an elongate member 3721 having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements 3722, and a removal tether 3724 having distal end attached to proximal ring element 3722 and proximal end attached to the elongate member 3721. The ring elements 3722 are self-expandable from a collapsed configuration to an expanded configuration and have a radial force that biases the ring elements 3722 toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by an intravascular microcatheter (not shown) through which the retrieval device 3720 is delivered inside the artery. Each ring element 3722 comprises a plurality of struts 3723. The outer mesh 3725 restrains the retrieval device 3720 and limits it to a certain diameter in the expanded configuration. The microcatheter is retracted proximally and each ring element 3722 disengages to form the maximum allowable diameter within the outer mesh.

Another embodiment of a mechanical clot retrieval device of the present invention is represented in FIG. 57. The retrieval device 3740 has an elongate member 3741 having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements 3742, and a removal tether 3744 having distal end attached to proximal ring element 3742 and proximal end attached to the elongate member 3741. The ring elements 3742 are self-expandable from a collapsed configuration to an expanded configuration and have a radial force that biases the ring elements 3742 toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by an intravascular microcatheter (not shown) through which the retrieval device 3740 is delivered inside the artery. Each ring element 3742 comprises a plurality of struts 3743. The tether net cover 3745 restrains the retrieval device 3740 and limits it to a certain diameter in the expanded configuration. The microcatheter is retracted proximally and each ring element 3742 disengages to form the maximum diameter allowed by the tether net cover.

Another embodiment of a mechanical clot retrieval device of the present invention is represented in FIG. 58. The retrieval device 3760 has an elongate member 3761 having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements 3762, and a control strut 3764 having distal end attached to proximal ring element 3762 and proximal end attached to the elongate member 3761 by adhesive bonds 3766. The ring elements 3762 are self-expandable from a collapsed configuration to an expanded configuration and have a radial force that biases the ring elements 3762 toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by an intravascular microcatheter (not shown) through which the retrieval device 3760 is delivered inside the artery. Each ring element 3762 comprises a plurality of struts 3763. Each strut 3763 has a crown element 3767. The crown element 3767 is connected to neighboring crown element 3767 by the ring to ring connection 3765. The ring to ring connection 3765 restrains the retrieval device 3760 in the collapsed configuration when it

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is advanced through the microcatheter (not shown). The microcatheter is retracted proximally and each ring element 3762 disengages to form the expanded configuration.

Another embodiment of a mechanical clot retrieval device of the present invention is represented in FIG. 59. The retrieval device 3780 has an elongate member 3781 having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements 3782, and a removal tether 3784 having distal end attached to proximal ring element 3782 and proximal end attached to the elongate member 3781. The ring elements 3782 are self-expandable from a collapsed configuration to an expanded configuration and have a radial force that biases the ring elements 3782 toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by an intravascular microcatheter (not shown) through which the retrieval device 3780 is delivered inside the artery. Each ring element 3782 comprises a plurality of struts 3783. The tether net cover 3785 restrains the retrieval device 3780 and limits it to a certain diameter in the expanded configuration. The device also comprises a tapered ring element at the distal end of the tether net cover 3785. The microcatheter is retracted proximally and each ring element 3782 disengages to form the maximum diameter allowed by the tether net cover 3785.

Another embodiment of a mechanical clot retrieval device of the present invention is represented in FIG. 60. The retrieval device 3800 has an elongate member 3801 having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a plurality of ring elements 3802, and a control strut 3804 having distal end attached to proximal ring element 3802 and proximal end attached to the elongate member 3801 by adhesive bonds 3806. The ring elements 3802 are self-expandable from a collapsed configuration to an expanded configuration and have a radial force that biases the ring elements 3802 toward the expanded configuration. In the collapsed configuration, the radial force is absorbed by an intravascular microcatheter (not shown) through which the retrieval device 3780 is delivered inside the artery. Each ring element 3802 comprises a plurality of struts 3803. Each strut 3803 has a crown element 3807. The crown element 3807 is connected to neighboring crown element 3807 by the ring to ring connection 3805. The ring to ring connection 3805 restrains the retrieval device 3800 in the collapsed configuration when it is advanced through the microcatheter (not shown). The ring elements are wrapped in an outer mesh/net cover 3808 which limits the diameter of the ring elements in the expanded configuration. The microcatheter is retracted proximally and each ring element 3802 disengages to form the expanded configuration with the maximum diameter allowed by the outer mesh/net cover 3808.

Another preferred embodiment of a mechanical clot retrieval device 3820 of the present invention is illustrated in FIGS. 61a-61c. The retrieval device 3820 is advanced through a microcatheter 3821 inside the patient artery and includes an activation tether 3824, having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a distal collar 3827, and a plurality of ring elements 3822 configured to the distal end of the activation tether 3824. The ring elements 3822 are self-expandable from a collapsed configuration to an expanded configuration and have a radial force that biases the ring elements 3822 in the expanded configuration. In the collapsed configuration, the radial force is absorbed by an intravascular microcatheter 3821 through which the retrieval device 3820 is delivered inside the artery. Each ring element

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3822, comprising a plurality of struts 3823, is interconnected by bridges 3825. The microcatheter 3821 is retracted and the activation tether 3824 is manually pulled proximally to compress the device and allow ring elements 3822 to reach the expanded configuration.

FIGS. 62a-62b shows a mechanical clot retrieval device 3840 of the present invention which is a slightly variant embodiment of the retrieval device as illustrated in FIGS. 61a-61c. The retrieval device 3840 is advanced through a microcatheter 3841 inside the artery and has an activation tether 3844, having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a distal collar 3847, and a ring element 3846 configured at the distal end of the activation tether 3844. The ring element 3846 is self-expandable from a collapsed configuration to an expanded configuration and comprises a radial force that biases the ring element 3846 to the expanded configuration. The ring element comprises a plurality of struts 3843. The micro catheter 3841 is retracted and the activation tether 3844 is manually pulled proximally to compress the device proximally and allow ring elements 3842 to reach the expanded configuration.

FIGS. 63a-63b shows a mechanical clot retrieval device 3860 of the present invention which is a slightly variant embodiment of the retrieval device 3840 as illustrated in FIGS. 62a-62b. The retrieval device 3862 is advanced through a microcatheter 3861 inside the artery and has an activation tether 3864 having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a distal collar 3867, a ring element 3866 configured at the distal end of the activation tether 3864, and a pair of removal tethers 3862 attached to the ring element 3866 having proximal ends that extend out of the artery. The ring element 3866 is self-expandable from a collapsed configuration to an expanded configuration and comprises a radial force that biases the ring element 3866 to the expanded configuration. In the collapsed configuration, the radial force is absorbed by the microcatheter. The microcatheter 3861 is retracted and the activation tether 3864 is manually pulled proximally to compress the device proximally and allow ring element 3866 to reach the expanded configuration.

FIGS. 64a-64b shows a mechanical clot retrieval device 3880 of the present invention which is a slightly variant embodiment of the retrieval device 3860 as illustrated in FIGS. 63a-63b. The retrieval device 3882 is advanced through a microcatheter 3881 inside the patient artery and has an activation tether 3884 having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a couple of collars 3887, a couple of ring elements 3886 configured at the distal end of the activation tether 3884, and a pair of removal tethers 3882 having distal ends attached to the ring element 3886 and having proximal ends attached to the collar 3887. The ring element 3886 is self-expandable from a collapsed configuration to an expanded configuration and has a radial force that biases the ring element 3886 to the expanded configuration. In the collapsed configuration, the radial force is absorbed by the microcatheter 3881. Each ring element 3886 comprises a plurality of struts 3883. The microcatheter 3881 is retracted and the activation tether 3884 is manually pulled proximally to compress the device and to allow ring element 3886 reach the expanded configuration.

FIGS. 65a-65d illustrates another preferred embodiment of a mechanical clot retrieval device 3900a of the present invention. The retrieval device 3900a is advanced through a microcatheter 3901 inside the patient artery and has a pair of

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activation tethers **3904** having distal ends that extend interior of the artery and proximal ends that extend exterior of the artery, a distal collar **3907**, and a plurality of ring elements **3902** configured to the distal end of the activation tether **3904**. The ring elements **3902** are self-expandable from a collapsed configuration **3900a** to an expanded configuration **3900b** and have a radial force that biases the ring elements **3902** to the expanded configuration **3900b**. In the collapsed configuration, the radial force is absorbed by an intravascular microcatheter **3901** through which the retrieval device **3900a** is delivered inside the artery. Each ring element **3902**, comprising a plurality of struts **3903**, is connected by bridges **3905**. Each strut includes a tether guide tube **3908**. The distal end of activation tether is passed through the guide tube **3908**. The microcatheter **3901** is retracted and the activation tethers **3904** are manually pulled proximally to compress the device proximally and to allow ring elements **3902** to reach the expanded configuration **3900b**.

FIGS. **66a-66c** illustrates a mechanical clot retrieval device **3920a** of the present invention which is a slightly variant embodiment of the retrieval device shown in FIGS. **61a-61c**. The retrieval device **3920a** is advanced through a microcatheter **3921** inside the patient artery and has a pair of activation tethers **3924** having distal ends that extend interior of the artery and proximal ends that extend exterior of the artery, a distal collar **3927**, and a plurality of ring elements **3922** configured to the distal end of the activation tether **3924**. The ring elements **3922** are self-expandable from a collapsed configuration **3920a** to an expanded configuration **3920b** and comprise a radial force that biases the ring elements **3922** in the expanded configuration **3920b**. In the collapsed configuration, the radial force is absorbed by an intravascular microcatheter **3921** through which the retrieval device **3920a** is delivered inside the artery. Each ring element **3922** comprising a plurality of struts **3923** and a limiting tether **3928** is interconnected by bridges **3925**. The microcatheter **3921** is retracted and the activation tether **3924** is manually pulled proximally to compress the device and to allow ring elements **3922** to reach the expanded configuration **3920b**. The limiting tether **3928** prevents the ring element from expanding beyond a certain diameter.

FIGS. **67a-67b** shows a mechanical clot retrieval device **3940** of the present invention which is a slightly variant embodiment of the retrieval device **3840** as illustrated in FIGS. **62a-62b**. The retrieval device **3940** is advanced through a microcatheter **3941** inside the patient artery and has an activation tether **3944** having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a distal collar **3947**, and a ring element **3946** configured at the distal end of the activation tether **3944**. The ring element **3946** is self-expandable from a collapsed configuration to an expanded configuration and has a radial force that biases the ring element **3946** to the expanded configuration. The ring element comprising a plurality of struts **3943** and a limiting tether **3948**. The microcatheter **3941** is retracted and the activation tether **3944** is manually pulled proximally to compress the device and to allow ring elements **3942** to reach the expanded configuration.

FIGS. **68a-68b** shows a mechanical clot retrieval device **3960** of the present invention which is a slightly variant embodiment of the retrieval device **3860** as illustrated in FIGS. **63a-63b**. The retrieval device **3962** is advanced through a microcatheter **3961** inside the artery and has an activation tether **3964** having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a distal collar **3967**, a ring element **3966**

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configured at the distal end of the activation tether **3964**, and a pair of removal tethers **3962** attached to the ring element **3966** having proximal ends that extend exterior of the artery. The ring element **3966** is self-expandable from a collapsed configuration to an expanded configuration and has a radial force that biases the ring element **3966** to the expanded configuration. In the collapsed configuration, the radial force is absorbed by the microcatheter **3961**. Each ring element **3966** comprises a plurality of struts **3963** and a limiting tether **3968**. The microcatheter **3961** is retracted and the activation tether **3964** is manually pulled proximally to compress the device and allow ring elements **3966** to reach the expanded configuration.

FIGS. **69a-69b** shows a mechanical clot retrieval device **3980** of the present invention which is a slightly variant embodiment of the retrieval device **3880** as illustrated in FIGS. **64a-64b**. The retrieval device **3980** is advanced through a microcatheter **3981** inside the artery and has an activation tether **3984** having a distal end that extends interior of the artery and a proximal end that extends exterior of the artery, a couple of collars **3987**, a couple of ring elements **3986** configured at the distal end of the activation tether **3984**, and a pair of removal tethers **3982** having distal ends attached to the ring element **3986**. The ring element **3986** is self-expandable from a collapsed configuration to an expanded configuration and has a radial force that biases the ring element **3986** to the expanded configuration. In the collapsed configuration, the radial force is absorbed by the microcatheter **3981**. Each ring element comprises a plurality of struts **3983** and a limiting tether **3988**. The microcatheter **3981** is retracted and the activation tether **3984** is manually pulled proximally to compress the device and allow the ring elements **3986** reach the expanded configuration.

The ring elements used in the above description are made of shape-memory material, preferably Nitinol. Remaining elements of the retrieval device as described herein are preferably formed of a material such as a stainless steel, a nickel-based super alloy, a spring steel alloy, particularly a composition sold under the trademark nitinol.

It will be apparent from the foregoing description that, while particular embodiments of the present invention have been illustrated and described, various modifications can be made without departing from the spirit and scope of the invention.

Modifications and additions can be made to the various embodiments of the invention described herein. For example, while embodiments may refer to particular features, the invention includes embodiments having different combinations of features. The invention also includes embodiments that do not include all of the specific features described.

The invention is not limited to the embodiments herein-before described which may be varied in construction and detail.

The invention claimed is:

1. A clot retrieval device comprising:

an elongate member and a plurality of clot engaging elements at a distal end of the elongate member, the clot engaging elements being self expandable between a retracted delivery configuration and an expanded deployed configuration; and

a plurality of restraining rings, each restraining ring positioned adjacent a clot engaging element of the plurality of clot engaging elements and including a restraining portion having a radially inner surface sized to receive a proximally extending tab of a clot engaging element of the plurality of clot engaging elements for

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biasing the clot engaging element in a retracted delivery configuration against the elongate member, wherein one restraining ring of the plurality of restraining rings is positioned proximally of each of the plurality of clot engaging elements in both the retracted delivery configuration and the expanded deployed configuration; and

wherein each restraining ring is releasable from an adjacent clot engaging element to allow the clot engaging element to expand into the deployed configuration.

2. A device as claimed in claim 1 wherein the elongate member extends exterior of the patient in use.

3. A device as claimed in claim 1 wherein the diameter of the clot engaging elements in the expanded deployed configuration is greater than the diameter of the clot engaging elements in the retracted delivery configuration.

4. A device as claimed in claim 1 wherein each of the plurality of restraining rings is connected to either the clot engagement elements, the elongate member, or to both.

5. A device as claimed in claim 1 wherein the each of the plurality of restraining rings includes a collar, an interior circumferential surface including the radially inner surface.

6. A device as claimed in claim 5 wherein the clot engagement elements comprise a plurality of struts and said plurality of restraining rings are configured to limit relative movement between at least a pair of said struts.

7. A device as claimed in claim 5 wherein the plurality of restraining rings are configured to limit relative movement between the clot engagement elements and the elongate member.

8. A device as claimed in claim 1 wherein the elongate member is configured to activate the plurality of restraining rings.

9. A device as claimed in claim 1, wherein the tab includes a bevel.

10. A clot retrieval device comprising:

an elongate member, a first clot engaging element and a second clot engaging element, the first clot engaging element distal of the second clot engaging element, the clot engaging elements being self expandable and having a sheathed delivery configuration, a deployed configuration, and a fully expanded configuration; and

at least one restraining ring having a restraining portion with a radially inner surface sized to receive a tab extending proximally from the first clot engaging element for biasing the first clot engaging element in the deployed configuration, wherein the radially inner surface abuts the tab in the deployed configuration;

wherein activation of the at least one restraining ring allows the first clot engaging element to expand into the fully expanded configuration.

11. A device as claimed in claim 10 wherein the sheathed delivery configuration comprises sheathing within the lumen of a microcatheter.

12. A device as claimed in claim 11 wherein unsheathing the clot engaging elements allows the first and second clot engaging elements to expand to the deployed configuration.

13. A device as claimed in claim 12 wherein the diameter of the first and second clot engaging elements in the deployed configuration is greater than the diameter of the first and second clot engaging elements in the sheathed delivery configuration.

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14. A device as claimed in claim 10 wherein the at least one restraining ring is axially moveable relative to the first and second clot engaging elements.

15. A device as claimed in claim 10 wherein the at least one restraining ring is connected to either the clot engagement elements, the elongate member, or to both.

16. A device as claimed in claim 10 wherein the at least one restraining ring includes a collar.

17. A device as claimed in claim 10 wherein the elongate member is configured to activate the at least one restraining ring.

18. A device as claimed in claim 10, wherein the restraining ring is coupled to and longitudinally fixed relative to the elongate member.

19. A device as claimed in claim 10, wherein the clot engagement element includes a sinusoidally shaped strut ring.

20. A device as claimed in claim 10, wherein the tab includes a bevel.

21. A clot retrieval device comprising:

an elongate member and at least one clot engaging element at a distal end of the elongate member, the clot engaging element being self expandable between a retracted delivery configuration, a deployed configuration, and a fully expanded configuration; and

a restraining ring including a restraining portion having a radially inner surface sized to receive a tab extending from the clot engaging element when the clot engaging element is in the retracted delivery configuration, and wherein the radially inner surface abuts the tab in the retracted delivery configuration,

wherein the restraining ring includes at least one collar movable relative to the clot engaging element; and wherein proximal movement of the restraining ring allows the at least one clot engaging element to expand from the deployed configuration to the fully expanded configuration.

22. A device as claimed in claim 21, wherein the restraining ring is coupled to the elongate member, and the radially inner surface of the restraining portion is located in or along one of a recess, hole, or groove.

23. A device as claimed in claim 21, further including a plurality of restraining rings and a plurality of clot engagement elements, each restraining ring being associated with a clot engagement element.

24. A device as claimed in claim 23, wherein the plurality of restraining rings and the plurality of clot engaging elements are aligned alternately along the elongate member.

25. A device as claimed in claim 21, wherein the clot engagement element includes a strut ring.

26. A device as claimed in claim 25, wherein the strut ring is sinusoidally shaped.

27. A device as claimed in claim 21, wherein the restraining ring is coupled to and longitudinally fixed relative to the elongate member.

28. A device as claimed in claim 21, wherein the restraining ring is positioned proximally of the clot engaging element in both the retracted delivery configuration and the expanded deployed configuration.

29. A device as claimed in claim 21, wherein the tab is a proximally extending tab.

30. A device as claimed in claim 21, wherein the tab includes a bevel.

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